PALEONTOLOGY LIBRARY
Museum Library

Volume 14 JANUARY, 1940 Number 1

JOURNAL OF PALEONTOLOGY

DEC 28 1939

A Publication of

The Paleontological Society

An Associate of the Geological Society of America

and

The Society of Economic Paleontologists and Mineralogists

A Division of the American Association of Petroleum Geologists

CONTENTS

Fauna of the basal Bonneterre dolomite (Upper Cambrian) of southeastern Missouri ..... *Christina Lochman* 1

Fauna of the Van Oser beds ..... *Clinton R. Stauffer* 54

Upper Devonian rugose corals of the Nevada limestone ..... *Erwin C. Stumm* 57

Upper Paleozoic cephalopods from central Hunan, China ..... *King Koo Chao* 68

Lebetocrinus, a new crinoid genus from the upper Borden of Indiana ..... *Edwin Kirk* 74

Aparchites canadensis, a new Devonian ostracode from the Onondaga of Ontario ..... *Madeleine A. Fritz* 77

Fossil Lygaeidae (Hemiptera) from Florissant ..... *Robert L. Usinger* 79

A toothless bird from the Cretaceous of Alberta ..... *R. M. Sternberg* 81

"Lucite" as an aid in studying hard parts of living and fossil animals . *Robert R. Shrock* 86

SOCIETY RECORDS AND ACTIVITIES

Illustrated card catalogue of North American Devonian invertebrates 88

Separate plates for sale 88

EDITORS

C. Wythe Cooke, for the Paleontological Society.

Norman D. Newell, for the Society of Economic Paleontologists and Mineralogists.

The Journal of Paleontology is published bi-monthly. The numbers issued in January, May, and September are sponsored by the Paleontological Society; those issued in March, July, and November are sponsored by the Society of Economic Paleontologists and Mineralogists.

The subscription price of the Journal of Paleontology is $6.00 per year prepaid to addresses in the United States, Mexico, Cuba, Puerto Rico, Panama Canal Zone, Republic of Panama, Dominican Republic, El Salvador, Bolivia, Colombia, Honduras, Nicaragua, Peru, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands.

Single numbers, $2.00 each.

Postage is charged extra: For Canada, 20 cents on annual subscriptions (total $6.20), for all other countries in the Postal Union, 40 cents on annual subscriptions (total $6.40).

The Journal will furnish reprints at cost. Orders should accompany manuscript.

Communications about the Journal, subscriptions, rates, memberships, change of address, and nonreceipt of preceding numbers should be addressed to Society of Economic Paleontologists and Mineralogists, P. O. Box 979, Tulsa, Oklahoma. Claims for nonreceipt of preceding numbers must be sent in within three months of the date of publication in order to be filled gratis. Communications in regard to advertising should be addressed to Norman D. Newell, University of Wisconsin, Madison, Wisconsin.

Communications in regard to manuscripts, or purely editorial matters should be addressed to Norman D. Newell, University of Wisconsin, Madison, Wisconsin, or C. Wythe Cooke, U. S Geological Survey, Washington, D.C.

Contributors are requested to instruct their photographers to illuminate fossils from the upper left side, the conventional manner. Plates should be arranged for publication at the size of 5 by 7 inches, exclusive of margins, heading, and title. Printed numerals of standard size and form may be obtained free from either editor. When requesting them state number of plates and the dimensions of each plate.

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in paragraph 4, section 538, P. L. and R., authorized April 3, 1935.

Additional entry as second-class matter at the Post Office at Menasha, Wis.

GEORGE BANTA PUBLISHING COMPANY, MENASHA, WIS.

Museum
Faxon

JOURNAL OF PALEONTOLOGY

A Publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS, *A Division of the American Association of Petroleum Geologists and* THE PALEONTOLOGICAL SOCIETY, *An Associate of the Geological Society of America*

VOLUME 14 JANUARY, 1940 NUMBER 1

FAUNA OF THE BASAL BONNETERRE DOLOMITE (UPPER CAMBRIAN) OF SOUTHEASTERN MISSOURI

CHRISTINA LOCHMAN
Mount Holyoke College, South Hadley, Mass.

ABSTRACT—The lower fifty feet of the Bonneterre dolomite in southeastern Missouri comprises a single zone carrying a late *Cedaria* fauna of over 61 species. The stratigraphy of the fossil zone is described, and the preservation, ecology and biologic relations of the fauna are discussed in detail. One new species of Porifera, six new species of Brachiopoda, three new species of Gastropoda, five new genera and 28 new species of Trilobita and one new genus and species of uncertain affinities are described.

THE LOWER 50 feet of the early Upper Cambrian Bonneterre dolomite of south eastern Missouri carries a fauna of late *Cedaria*-zone age. The fossil zone was discovered in 1916 by Dr. E. O. Ulrich in a small quarry near Jaydee, Ste. Genevieve County, Missouri; and in 1928 a preliminary faunal list was published by Weller and St. Clair (14a) in the Ste. Genevieve County report.

During the field seasons of 1930, '32 and '33 the author traced the fossil zone throughout its area of outcrop (fig. 1) in Ste. Genevieve, St. Francois and portions of Madison Counties and made the extensive collections of fossils upon which this paper is based. The types and figured specimens are in the U. S. National Museum.

The Bonneterre fauna is one of the largest and most varied *Cedaria* faunas known and is the first to be described in its entirety. It comprises a total of 61 species—13 inarticulate brachiopods, 42 trilobites, four gastropods, one porifer and one of undetermined affinities, as well as undescribed fragments of crinoids, a merostome and calcareous algae.

The author takes this opportunity to express her deep gratitude and appreciation to those who, by their invaluable aid and assistance, have made this work possible. She is especially indebted to Dr. Josiah Bridge of the U. S. Geological Survey, who suggested the problem and has followed its progress with most enthusiastic interest. She wishes to thank Dr. C. E. Resser for his kindness and generosity in permitting her access to the Cambrian collections at the United States National Museum. Dr. G. A. Cooper very kindly permitted the author to use his personal camera in photographing a number of the specimens. The University of California Museum very kindly loaned her the type of *Norwoodia quadrata* (Whitfield). The many pertinent criticisms and suggestions of Professor E. W. Berry of Johns Hopkins University and Dr. H. A. Meyerhoff of Smith College were of inestimable value to the author in every phase of the study.

THE BONNETERRE DOLOMITE

The Upper Cambrian formations of south eastern Missouri outcrop around the pre-Cambrian igneous rocks of the St. Francois Mountains in a series of concentric bands,

which dip at a low angle off the crystalline area. On the northeastern side the monoclinal dip is interrupted in St. Francois County by a complexly faulted area lying between the towns of Doe Run and Bonneterre, and in western Ste. Genevieve County by the Farmington anticline extending for over 13 miles along a northwest-southeast axis and bounded along the northeastern side by another complexly faulted area.

The formations represent a series of transgressing beds deposited around and upon the rugged, deeply dissected crystallines of the pre-Cambrian land area. The section begins with the Lamotte sandstone, a basal sandstone extremely variable in texture and thickness. It is overlain by the Bonneterre dolomite, indicating the gradual submergence of the old land area and cessation of sedimentation from the Canadian Shield.

The Bonneterre dolomite is named from the town of Bonneterre in St. Francois County, where the upper 200 feet of the formation are well exposed. The name was first published by F. L. Nason (5) in 1901, at which time the formation was recognized essentially in its present status except for the inclusion of the lower beds of the Davis. In 1908 Buckley (2) redefined the formation in its present usage.

Through St. Francois, Ste. Genevieve and Madison Counties the Bonneterre outcrops in an irregular band east of the Lamotte sandstone. In the north the formation underlies the broad Bonneterre plain, over eight miles wide; but to the south the outcrops narrow to one mile in the vicinity of Mine La Motte, and increase again to four miles in Madison County farther south.

The formation varies considerably in thickness throughout the area, for it overlaps the Lamotte and is to a certain degree still affected by the irregularities of the pre-Cambrian surface. The average thickness is 375 feet; but in the north on the Bonneterre plain a maximum of 448 feet has been recorded at Delassus. The thickness decreases regularly southward, with an average of 200 feet in Madison County and a minimum of 50 feet where the Bonneterre lies directly on the rhyolite porphyry.

A two-fold lithologic division can be recognized within the Bonneterre—a basal 50 feet, which is an intricate sequence of interbedded and intergrading glauconitic sandstones, fine gray and yellow shales, fossiliferous crystalline limestones, and barren white or pink dolomites; and a 200–300-foot upper portion, which is essentially a massive-bedded barren crystalline dolomite.

The Bonneterre dolomite appears to be perfectly conformable with the underlying Lamotte sandstone. St. Clair (14b) has postulated a slight unconformity between the Lamotte and the Bonneterre throughout southeastern Missouri, but all field evidence is to the contrary. At several localities (82.13, 76.24, 76.29, 76.35, see list) excellent sections of the contact are exposed. The contact between the two formations can everywhere be placed only arbitrarily at the base of the first sandstone that has an appreciable glauconitic or calcareous content, since all the lower beds of the Bonneterre are arenaceous in character. No evidence of a break in sedimentation can be demonstrated as the pure white or yellow sandstones of the Lamotte pass directly upward into the basal sands of the Bonneterre, in which the glauconitic and calcareous material becomes increasingly important and the arenaceous less until lenses of impure limestones and dolomites appear, which in turn grade upward into purer limestone and dolomite beds. The transitional character of the basal Bonneterre was well known to St. Clair (14c) who gives a section on the north branch of Establishment Creek, which is an excellent example of the condition. At all outcrops examined the limestones and dolomites of the lower Bonneterre carry arenaceous and argillaceous impurities of varying amounts for approximately 50 feet above the contact.

Moreover, it is very doubtful whether the Bonneterre outliers mentioned by St. Clair (14d) as lying in depressions on the surface of the Lamotte sandstone actually occupy such a position, for their topographic and areal expression offers no support to such an interpretation. These outliers all occur within Ste. Genevieve County in three small areas on the flanks of the Farmington anticline. They lie only a mile and a half or less from continuous outcrops of the Bonneterre, and in each case are located on or near the top of elevations rising between small creek beds. In the field they all appear to be nor-

mal erosional remnants resulting from the removal of the Bonneterre formation from the flanks of the anticline.

Thus all the available field evidence indicates that the Lamotte-Bonneterre contact is conformable.

The dissection of the Farmington anticline may be regarded as directly responsible for the exposure of the beds carrying the Bonneterre fauna. The fossiliferous crystalline limestones occur only in the basal beds of the formation along the flanks of this anticline, and throughout most of the area of outcrop these beds lie over 200 feet below the surface. When they reappear on the eastern flank of the St. Francois Mountains their lithologic and faunal characters are entirely different. On the western flank of the St. Francois Mountains in Washington County the basal Bonneterre is reported by C. L. Dake (3) to be everywhere unfossiliferous, a single valve of *Dicellomus politus* (Hall) from a drill core being the only specimen ever recorded.

Outcrops of the Bonneterre in Madison County close to the pre-Cambrian crystallines of the east side of the St. Francois Mountains were examined. The basal beds consist of an intercalated, laterally intergrading series of thin conglomeratic dolomites (usually near the base), massive crystalline dolomite, thin-bedded dense dolomites, and thin beds and lenses of shales and shaly limestones. The latter sporadically carry in great abundance the valves of three brachiopod species. These shaly brachiopod lenses occupy varying stratigraphic positions (from 10 to over 75 feet) above the Lamotte-Bonneterre contact, but all are apparently the same age and are to be correlated generally with the main faunal zone to the north. The peculiarities appear to be due entirely to local conditions of sedimentation. The brachiopod lenses represent former small, possibly abnormal, areas of mud flats lying close to the shore in protected or even land-locked parts of the irregular estuaries and embayments, which together with steeply sloping headlands and innumerable scattered islands characterized the early Upper Cambrian shore of this region.

Good exposures of the main fossil zone around the Farmington anticline can be found in the sections at the localities cited on page 4. Because of the variable lithology of the basal beds and of the fact that the fossils are found almost exclusively in the limestones, some variation in the position of the zone above the contact and in the actual thickness of the zone, as well as in its lithology, occurs between the different outcrops, although certain broad areal units are present. Thus on the northwest flank of the anticline around Jaydee the base of the fossil zone always appears between 20 and 30 feet above the contact, a two-fold separation of the zone into a lower thick-bedded limestone and an upper thin-bedded series occurs. The following lithologic sequence, in which beds 3 to 6 represents the fossil zone, can be generally recognized.

SECTION IN VICINITY OF JAYDEE QUARRY, LOCALITY 82.13

	Ft.	*In.*
Bonneterre dolomite		
7. Dolomite, light-gray, dense, massive bedding.		
6. Limestone, gray mottled with yellow patches, fine-grained to dense, extremely argillaceous, very thin-bedded, glauconitic...	1	6
5. Limestone, gray mottled with yellow, fine-grained, argillaceous and arenaceous, medium to thin bedded, glauconitic.....	1	6
4. Limestone, extremely arenaceous and glauconitic, dark-green, cross-bedded.....		0–18
3. Limestone, blue-green, glauconitic, thick-bedded, with varying amounts of blue argillaceous material occurring in lenses or thin beds.....	6	
2. Sandstone, buff, light to dark green, with a noticeable amount of glauconite and calcareous material, generally thick-bedded...	25	
Lamotte sandstone		
1. Sandstone, buff to reddish-brown		

On the eastern flank of the anticline from Fourche à du Clos Creek southward to locality 76.21, one mile west of Avon, the sections carry a higher proportion of dolomite in the basal beds, which results in the base of the fossil zone (beds 6 and 7) appearing higher in the section (35–40 feet above the contact) where the first limestones occur. At a few outcrops in this area the basal glauconitic sandstones pass directly into dolomites, and both limestones and fossil zone are absent.

SECTION IN VICINITY OF LOCALITY 76.21

	Ft.
Bonneterre dolomite	
8. Dolomite, dense, light-gray, massive.	
7. Limestone, gray mottled with yellow patches, dense to fine-grained, arenaceous and argillaceous with the shale content prominent in the upper portion, thin-bedded, glauconitic	5
6. Limestone, gray, medium-grained, with thin blue shale lenses, 2- to 3-inch bedding, glauconitic	4
5. Dolomite, light gray, fine-grained, very little glauconite, well-bedded, locally contains shale lenses or beds or sand	20
4. Limestone, extremely arenaceous and glauconitic, brachiopod fragments	1–2
3. Dolomite, fine-grained, light-gray to pink with scattered glauconite giving a greenish tint, 2- to 3-inch bedding, occasional brachiopod fragments	8
2. Sandstone, light to dark green depending upon the glauconite content, calcareous material, generally friable, thick-bedded	7
Lamotte sandstone	
1. Sandstone, yellow to brown.	

In the three easternmost fossil localities (76.20, 76.28 and 76.39) limestones again appear low in the basal beds of the formation, and the fossil zone begins 20–25 feet above the contact.

Such variable conditions definitely indicate that the dolomitization of the basal beds, though purely local in character, is the principal factor controlling the occurrence of fossils and the elevation and thickness of the fossil zone.

LIST OF FOSSIL LOCALITIES

The collections were obtained from the localities listed below. Each is given a county and an individual number separated by a decimal. County numbers are assigned by the Department of Geology of the Missouri School of Mines, and locality numbers by the author. With the exception of the Fredericktown area, all localities fall within the limits of recently mapped quadrangles of the U. S. Geological Survey topographic atlas. As all these sheets have been mapped geologically by the Missouri Bureau of Geology and Mines within the past 15 years, the positions of localities can be accurately established. Those in Madison County are plotted on the forty-year-old Mine La Motte sheet, and are less accurate.

Photographs of all localities are available in the author's files.

St. Francois County.—82.11 SE ¼ SE ¼ sec. 24, T. 36 N., R. 5 E. In stream bed two miles north of Farmington on St. Louis road and one-fourth mile west of the St. Louis road. Fossil beds occur halfway up the cliff on west side of ford and in stream bed 50 yards farther upstream.

82.12 NW ¼ NW ¼ sec. 19, T. 36 N., R. 6 E. On northernmost fork of Wolf Creek where it crosses the St. Louis road 2½ miles north of Farmington. The outcrop is in a small cliff southwest of the stream above the Lamotte sandstone, which appears in bed of creek east of road. The bed carrying the fossils is just 20 feet above the sandstone. The specimens came from a gray coarse-grained lens near the road.

82.13 NW ¼ NW ¼ sec. 18, T. 37 N., R. 6 E. In a quarry one-eighth mile south of Jaydee, on east side of old St. Louis road. From the outcrop of the upper Lamotte sandstone in the bed of Terre Bleue Creek, the section through the basal beds of the Bonneterre can be traced continuously up the road to the floor of the quarry.

82.14 SE ¼ SE ¼ sec. 12, T. 37 N., R. 5 E. One-fourth mile west of Jaydee, on north side of the road to Bonneterre. Bonneterre limestone outcrops in gullies on both sides of road up a low hill west of small tributary of Terre Bleue Creek.

82.15 SW ¼ NE ¼ sec. 5, T. 35 N., R. 6 E. Two and one-half miles south of Farmington on U. S. Routes 61 and 67, and one-fourth mile east of the highway on the Butterfly Lake road, in bed of a tributary of Wolf Creek.

82.16 NW ¼ SW ¼ sec. 4, T. 35 N., R. 6 E. On Wolf Creek one-fourth mile north of bridge over the creek on U. S. routes 61 and 67, three miles south of Farmington. Nearly continuous outcrops of section from top of Lamotte sandstone to upper part of Bonneterre dolomite. Fossil zone partly covered by sand but with many loose boulders marking its position.

82.17 NW ¼ NW ¼ sec. 16, T. 35 N., R. 6 E. A small draw directly south of the ford on Wolf Creek and 0.3 mile south of Back Creek. Several thin shaly dolomites carrying brachiopods are overlain by massive green and pink unfossiliferous dolomite. Outcrop is comparable to Madison County localities.

82.18 SE ¼ SW ¼ sec. 6, T. 37 N., R. 6 E. In gullies along the road and in stream bed of a small western tributary of Bouyer Creek, 0.3 mile east of old St. Louis road.

82.19 NW ¼ NE ¼ sec. 7, T. 37 N., R. 6 E. Many fossiliferous lenses occur in the limestone ledges outcropping in bed of Bouyer Creek fifty yards south of the road.

82.20 SW ¼ SW ¼ sec. 5, T. 37 N., R. 6 E. A thin-bedded shaly limestone exposed for a short distance in the bed of a small eastern tributary of Bouyer Creek immediately south of the road.

82.21 NE ¼ SE ¼ sec. 6, T. 37 N., R. 6 E. On a small eastern tributary of Bouyer Creek 0.2 mile north of the main east-west road. The stream bed and road sides covered with loose boulders of fossiliferous crystalline limestone.

82.22 NE ¼ NW ¼ sec. 8, T. 37 N., R. 6 E.

Outcrop of limestone in bed of Andrews Branch at old ford one-half mile southwest of the road along the northern boundary of the old French land grant.

82.23 SE ¼ SE ¼ sec. 5, T. 37 N., R. 6 E. Along the roadside and on a small unmapped creek 0.4 mile west of the crossroads to Thurman. The outcrop is chiefly boulders of mottled yellow limestone widely scattered along the roads.

82.24 NW ¼ NE ¼ sec. 6, T. 37 N., R. 6 E. Outcrops of 40 feet of the lower Bonneterre occur on an eastern tributary of Bouyer Creek two miles northeast of Jaydee. The strata here show a low southwest dip, and most are above the fossil zone; but in the stream bed 20 feet below the northwest side of the road, shaly fossiliferous beds were found.

82.25 SW ¼ SE ¼ sec. 29, T. 38 N., R. 6 E. Outcrops along north side of the main road through French Village, 0.1 mile south of the Catholic Church.

82.26 SE ¼ SW ¼ sec. 28, T. 38 N., R. 6 E. Shaly limestone beds in Goose Creek, at bend in the stream south of road, 0.3 mile east of French Village.

Ste. Genevieve County.—76.20 SE ¼ SE ¼ sec. 12, T. 35 N., R. 7 E. Fossiliferous outcrops in channel of Saline Creek 1.2 miles southeast of the schoolhouse at Avon, and 150 yards upstream from the igneous dike.

76.21 NW ¼ SW ¼ sec. 11, T. 35 N., R. 7 E. A continuous exposure of the lower and middle parts of the Bonneterre occur along the road one mile west of Avon. Yellow mottled fine-grained limestones near the base of the hill mark the fossil zone.

76.22 NE ¼ SE ¼ sec. 16, T. 36 N., R. 6 E. Outcrop on north side of road approximately five miles east of Farmington on the Burke road, where the road crosses the west fork of Taylor Branch.

76.23 SW ¼ SW ¼ sec. 8, T. 36 N., R. 6 E. Thin shaly limestone exposed on the west bank of Camp Creek near the head of the stream just south of the Illinois Southern Railway tracks.

76.24 NW ¼ NE ¼ sec. 25, T. 37 N., R. 5 E. Outcrop of fossil zone on southwest bank, seven feet above the bed of Salem Creek one-half mile west of the old St. Louis road. The ground is covered with many boulders of weathered very fossiliferous limestone.

76.25 Center of SE ¼ sec. 17, T. 37 N., R. 6 E. The largest western outlier of Bonneterre, forming a low hill over which the Thurman road passes, one mile south of Thurman. On north side of hill are fossiliferous limestone lenses and on the south side the zone is more shaly with many weathered surfaces covered with crinoid stems.

76.26 NE ¼ SE ¼ sec. 29, T. 37 N., R. 7 E. Thin-bedded mottled yellow fine-grained limestones and dolomites, sparingly fossiliferous, outcrop in the valley of an unmapped creek 13 miles northeast of Farmington on the Burke road.

76.27 SW ¼ SW ¼ sec. 36, T. 38 N., R. 6 E. Fine-grained shaly limestones outcropping in a cliff on the northwest bank of Fourche à du Clos Creek, 50 yards downstream from a small eastern tributary. Best collecting from coarse-grained lenses weathered loose as boulders in the stream bed.

76.28 SE ¼ SW ¼ sec. 36, T. 36 N., R. 7 E. Residual boulders of fossiliferous limestone on the surface of forest floor at top of hill above the old Cape Girardeau Northern Railway cut. This outcrop is about 40 feet above the Lamotte sandstone, which is exposed in the creek south of the railroad. In the railroad cut is an excellent outcrop of the thickest (20 feet) of the few shale beds in the basal Bonneterre.

76.29 SE ¼ SW ¼ sec. 18, T. 37 N., R. 6 E. Continuous outcrops of fossiliferous limestone in the gullies along the road 1.3 miles southeast of Jaydee and 0.3 mile east of old St. Louis road. The zone lies 25 feet above the Lamotte sandstone, which outcrops at foot of hill.

76.33 NE ¼ SE ¼ sec. 24, T. 37 N., R. 5 E. Exposures of fossil zone in two small quarries 1.5 miles south of Jaydee and 0.3 mile west of old St. Louis road. The section is essentially the same as that exposed in the quarry at locality 82.13.

76.34 NE ¼ SE ¼ sec. 14, T. 37 N., R. 6 E. A few poorly exposed ledges scattered along the Potosi and Ste. Genevieve road for a distance of about 200 yards 5¾ miles east of Jaydee.

76.35 SW ¼ NW ¼ sec. 13, T. 37 N., R. 6 E. Fossil zone outcrops where the Potosi and Ste. Genevieve road crosses a small draw forming the southern headwaters of Fourche à du Clos Creek, one-half mile southwest of the cross-roads. For one-half mile along the stream bed to the west occurs a continuous outcrop of more than 40 feet of the lower Bonneterre beds.

76.36 NW ¼ NE ¼ sec. 13, T. 37 N., R. 6 E. Thin-bedded shaly yellow limestone and a few boulders of crystalline fossiliferous limestone along the Hickory Creek Road, 0.4 mile southeast of Potosi and Ste. Genevieve road.

76.37 SW ¼ NW ¼ sec. 20, T. 37 N., R. 7 E. Exposure of shaly fine-grained limestone on Fourche à du Clos Creek two miles north of the Potosi and Ste. Genevieve-Hickory Creek cross-roads corner.

76.38 SE ¼ NE ¼ sec. 2, T. 37 N., R. 6 E. A section of the lower 70 feet of the Bonneterre in cliffs along Hickory Creek from the ford to the Lamotte-Bonneterre contact. The fossil zone is more than 10 feet thick and extends several hundred yards upstream along the south bank.

76.39 NE ¼ NW ¼ sec. 31, T. 36 N., R. 8 E. In gullies on the southeast side of the county road 0.3 mile north of Coffman. The outcrop exposes the upper Lamotte sandstone and 20 feet of the lower Bonneterre. A pebble limestone occurs in the top beds and fossils were collected at the same elevation above the contact.

Madison County.—91.7 NE ¼ SE ¼ sec. 29, T. 34 N., R. 7 E. On dumps and in a small outcrop of sandy conglomeratic dolomite at the old Jack diggings one mile east of Mine La Motte.

91.8 SE ¼ SE ¼ sec. 6, T. 33 N., R. 7 E. Outcrop along the southern bank of Little St. Francois River both up- and downstream from

the bridge of the St. L. I. M. & S. Railway, Belmont Branch.

91.9 NW ¼ SW ¼ sec. 7, T. 33 N., R. 7 E. Thin shaly dolomites filled with valves of a single species of brachiopod are exposed in a small quarry 200 yards south of U. S. Route 70, one mile west of Fredericktown.

PRESERVATION OF THE FAUNA

The preservation of the Bonneterre fauna is exceptionally good considering the character of the matrix in which it occurs. The present condition of the fossils has been determined by several factors: the primary deposition, the subsequent replacement of the organic material, and the texture of the matrix of the fossil horizon.

The factor of primary deposition is the most important, as it determined the condition in which the shells and tests were buried; and because of a segregation by wave action, it has controlled the occurrence of good fossil material. Fossils are scattered very sparingly throughout the entire zone but occur abundantly enough to afford good collecting only in localized pockets or lenses of very irregular distribution. The pockets were apparently formed on the sea floor by wave action sweeping the animal debris together in isolated patches and leaving other areas quite clean, a process which may be observed along present coasts. A definite wave sorting of the animal debris with respect to size and shape is recognizable in the collections. The material from some lenses consists predominantly of trilobite larvae, the smallest adult trilobite species, and *Pelagiella*, with only occasional fossils of the larger trilobites; while in other lenses the cranidia and pygidia of the larger trilobites dominate. The action of wave sorting in respect to shape is especially important as it led to a discrimination between the different parts of the disarticulated trilobite test, which has made the later correct association of parts extremely difficult.

The constant wash of the waves also affects the completeness of the fossils. All the trilobite tests have been dismembered along lines of weakness, the facial suture and the articulations of the thorax; and frequently the more exposed parts of the cranidium and pygidium have been snapped off, such as the genal and pygidial spines of *Tricrepicephalus*, the genal and occipital spines of the Norwoodidae, and the stalked eyes of *Millardia*. Among the brachiopods the thick, many layered shells of *Dicellomus* very effectively resisted the shock of the waves, but most of the thinner-shelled species are fragmentary. The crinoid calyxes and stems and the merostome tests were badly broken up and are now represented only by unidentifiable fragments. Well-rounded and irregular pellets of brown calcite, which occur scattered through the fossiliferous lenses, appear to represent small well-worn fragments of organic origin comparable to modern coral sands.

Although the tests and shells were subjected to many vicissitudes during deposition, their subsequent preservation has been excellent. The calcareo-chitinous tests of the trilobites underwent such perfect molecular replacement of the organic material by small calcite crystals that all the most minute details of surface markings have been retained even on the microscopic species. Very rarely a coarser type of replacement by chalcopyrite has occurred. The valves of the brachiopods retain the calcified layers of the original shell. On many of the *Dicellomus* valves the original blue-green nacreous lustre of the inner layers is still present, and on a few specimens the exterior color markings, bright orange bands alternating with white, have been observed.

Because the Bonneterre has never suffered severe deformation, the fossils show no distortion; but another feature, the texture of the limestone matrix, is a very important factor in the recovery of identifiable specimens. The replacing calcite has, as a rule, the same resistance to weathering as the limestone matrix, so that on old surfaces the specimens are too deeply weathered to be identifiable. A fresh surface must be broken to obtain good fossils, and the texture of the rock controls the manner in which they break out. In a fine-grained limestone, the size of the calcite crystals of the fossil and of the matrix is so similar that the fractures run directly through the fossil. However, in a coarse-grained matrix the contrast is sufficient to cause the fossils to break out more or less cleanly. In certain localities these coarse-grained porous beds and lenses have been thoroughly permeated by the ground water. There the calcite of the fossil may

have been entirely removed, leaving only an iron stain to mark its former position; or else the leaching has loosened the fossils in the matrix so that they break out very cleanly but with the outer surface destroyed. The best specimens are obtained by cleaning freshly broken material.

ECOLOGY OF THE FAUNA

The prolific fauna of the Bonneterre indicates that conditions must have been especially favorable for marine life in the early Upper Cambrian sea of Missouri. The various lines of evidence derived from the nature of the sediments, the preservation of the fauna, and the biologic characters of the species all point to a warm-temperate shallow-marine environment.

The presence of large amounts of fine arenaceous and argillaceous material in the limestones, as well as lenses of cross-bedded glauconitic limestones,[1] indicates that the area lay near the shore under the influence of shifting littoral currents. Patches of comminuted brachiopod shells, and the wave sorting and transportation which the shells and tests apparently underwent before burial further attest the shallowness of the sea and the strong wave action to which its bottom was subjected.

An examination of the biology of the species reveals the dominantly neritic character of their habitat. The thick-shelled *Dicellomus*, well adapted to surf conditions, dominates the brachiopods both in number of species and of individuals. Of the distinctly less numerous thin-shelled species two specimens of *Obolus maesche* Lochman have been found that show a break in the shell, which has subsequently been healed. Among the extremely varied trilobite fauna may be found adaptations to all types of benthonic life. *Tricrepicephalus* and *Meteoraspis* were apparently active crawling forms; *Kingstonia*, *Ankoura* and *Norwoodella* burrowing genera; and the agnostids *Menomonia* and *Millardia* probably belonged to the infauna. Of the entire assemblage, only *Hyolithes* could afford evidence of deep water, but, as it is a pelagic form, it could easily be washed into coastal areas by storms.

[1] A good example is in the section at Jaydee quarry, locality 82.13.

The large number of genera and species suggests a temperate to warm-temperate climate, but the absence of certain genera and species common to the Alabama and Texas faunas indicates cooler waters than those of the Gulf region. The great numbers of trilobite moults and larvae, and the abundance of brachiopod individuals of all sizes point also to a sufficient, even abundant, food supply.

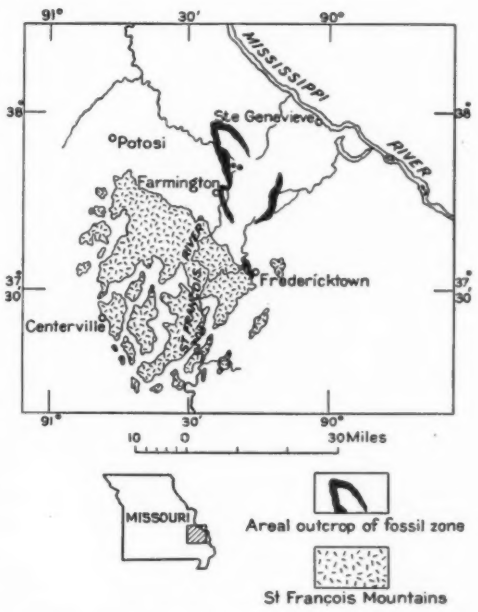


FIG. 1—Location of the Bonneterre fossil zone.

Thus it is postulated that the environment of the Bonneterre fauna was the well-lighted, agitated waters of a shallow epeiric sea.

COMPOSITION OF THE FAUNA

Trilobite and brachiopod remains dominate the collections from the Bonneterre, but the fossils alone do not give a true picture of the marine community of that period. They represent only those animals having exoskeletons strong enough to withstand comminution until they were buried. Also, most of the trilobites represent moults, and the only certainly dead individuals are the two enrolled immature agnostids. It seems quite possible that species of crinoids,

sponges, and *Kinsabia varigata* Lochman were of equal importance in the living fauna, but the destruction of their more delicate tests has now pushed them into a secondary position. Because of their absence among the fossils, too frequently the soft-bodied animals are completely forgotten, although during the Cambrian they must have formed, both in number of species and individuals, a good three-fourths of the total assemblage. The best concept of the variety and the balance of Cambrian marine communities is gained from the fauna of the Burgess shale.

The brachiopod fauna of the Bonneterre is distinctive for the number of small, sturdy, rather generalized species, which exhibit a striking mixture of progressive and unprogressive forms. The three poorly represented genera of the Paterinidae are making their last appearance and are clearly remnants of the Middle Cambrian faunas. Of the Obolidae, *Obolus* and *Lingulella* continue along in a conservative position, but the new *Dicellomus*, well adapted to local conditions, dominates the fauna. The Neotremata are modestly but amply represented by a species each of *Acrotreta* and *Linnarssonella*. The brachiopod assemblage, as a group of shallow-water surf dwellers, followed closely the edge of the advancing sea and disappeared from an area as the water became deeper.

The trilobites, however, offer the best opportunity for detailed study. An examination of great numbers of excellently preserved specimens served to confirm many of the observations of European authors. Structural features common to all genera and species appear to be, first, a punctate inner surface of the carapace and, second, radiating venations over the frontal limb and ocular platforms of the cephalon. The functions of these structures will never be truly known, but a number of explanations have been offered. The punctations may mark the location of respiratory pores or blood vessels, and the venation may be the trace of hepatic, vascular or neural canals. Their universal occurrence proves conclusively that they are expressions of internal anatomical structures characteristic of the whole class and must not be used as diagnostic generic or specific features.

Three distinct types of surface ornamentation may be found among the Bonneterre trilobites. The markings may consist of, first, only plications, second, only granules, or, third, a combination of plications and granules. The first type is illustrated by *Kingstonia* and *Ankoura*. The carapace is smooth except for a series of parallel transverse ridges, which run across the frontal border and out a short distance on the marginal border of the free cheek. The second type occurs in species of *Menomonia* and *Millardia*. The carapace bears granules of one, two, or more sizes scattered regularly or irregularly over the test. *Tricrepicephalus* and *Coosella* are good examples of the third type. All portions of the carapace except the marginal borders are covered with granules —in *Coosella* exclusively of a single small size, but in *Tricrepicephalus* of two sizes. In the latter genus the coarse granules have a small central pit which suggests that they may have functioned as pores. The marginal border and genal spines of the cephalon, the terminations of the pleurae, and the marginal border and spines (in *Tricrepicephalus*) of the pygidium are covered by short imbricating ridges paralleling the edge of the carapace. High magnification reveals that these ridges owe their origin to a linear orientation of the fine granules near the edge of the carapace. The ridges are likewise very distinct and parallel on the doublure of the carapace, and may possibly be of the nature of incremental lines.

The Agnosta, Opisthoparia and Proparia are all represented, with the Opisthoparia as the dominant group. Although fully appreciating the artificiality of grouping trilobite genera into families largely on the basis of adult external appearance, the author is forced to follow this method, for the Bonneterre material offers no other alternative. The majority of the genera appear to belong to recognized families.

The two enrolled immature agnostids are almost unique specimens in the American Cambrian and are the first recorded species of that kind. The specimens, though small, illustrate perfectly the relation of the marginal irregularities of the carapace to the mechanical efficiency of enrollment as indicated by O. Jaekel (4).

Of the Opisthoparia *Tricrepicephalus* and

Kingstonia are the outstanding genera. Conditions in the Missouri region appear to have been especially favorable for *Tricrepicephalus*, for here the genus reached a peak of specific variation. Specimens representing all stages of development from the protaspid to the senile holaspid have been obtained in great abundance, affording a complete ontogenetic series for the genus. Its closest relative, *Meteoraspis*, so prominent in the Cordilleran faunas, is represented by only one unimportant species. Among the *Kingstonias*, *K. spicata* Lochman is unique in the possession of a posterior median spine on the pygidium. The species is apparently a local peculiarity, for nothing like it is known from any other Dresbach fauna.

The Proparia have an unusually large and fine representation of genera and species considering the age of the fauna, and they comprise a good quarter of the number of specimens. Such a large assemblage of well-established Proparian species in an early Upper Cambrian fauna gives additional support to the theory of the antiquity of this group proposed by Frank Raw (6). Although a change was suggested by Elsa Warburg (13) from a study of Walcott's plates, an examination of the specimens both in the Bonneterre material and from the Wisconsin collections indicates that the Menomonidae should be retained in the Proparia. On plate 4 a number of unretouched pictures of species of the two genera give a good idea of the course of the facial suture, which cuts the lateral margin just in front of the genal angle.

Dr. C. E. Resser has recently placed *Millardia* in synonomy with *Menomonia* (8). The author cannot subscribe to this decision, as she believes that the differences existing between the genotypes of these two genera constitute valid generic distinctions. The characteristics of each genus are as follows:

Menomonia

Genotype, *Menomonia calymenoides* (Whitfield)

Outer surface granular.
Cranidium: Glabella triangular, short; proportion of free cheek: glabella = 1:2; three short glabellar furrows; frontal limb concave.
Frontal border broad, subtriangular-elliptical.
Palpebral lobes elevated.
Course of facial suture straight forward in front of eye, diagonal curve behind eye, cutting lateral margin almost at genal angle.
Suture normal, open.
Free cheek large, subtriangular; marginal furrow well-defined along front.
Thorax including 42 segments; axial lobe strongly convex; pleural lobes strongly curved.
Pygidium very small, subsemicircular; 2 or 3 segments on axial lobe.
Described species:
Menomonia calymenoides (Whitfield).
Menomonia modesta Lochman, n. sp.

Millardia

Genotype, *Millardia semele* Walcott.

Outer surface granular.
Cranidium: Glabella triangular, short; proportion of free cheek: glabella = 1:2; three short glabellar furrows; frontal limb concave.
Frontal border a narrow, slightly arcuate, vertical rim.
Palpebral lobes on stalks.
Course of facial suture straight forward in front of eye, diagonal curve behind eye, cutting lateral margin almost at genal angle.
Suture tight.
Free cheek elongate, suboblong; marginal furrow very shallow.
Thorax including 27 (possibly 30) segments; axial lobe moderately convex; pleural lobes slightly curved.
Pygidium small, transverse; 2 or 3 segments on axial and pleural lobes.
Described species:
Millardia semele Walcott.
Millardia avitas Walcott.
Millardia optata (Hall).
Millardia magnagranulata Lochman.
Millardia prominens (Resser).

Millardia buttsi (Resser), *M. texana* (Resser), and *M. lochmanae* (Resser) are synonyms of *Millardia avitas* Walcott.

The tabulation brings out several points of difference between the two genera which the author believes constitute a valid basis for generic separation. (1) The number of thoracic segments: The presence in *Millardia* of at least 27 thoracic segments, with a possibility of two or three more, is definitely known from the specimens of *M. semele* figured by Walcott (11). As regards *Menomonia*, the author has examined the associations of thorax and cranidium at the National Museum and also in collections at the University of Wisconsin, and believes it is highly probable that this is the correct association.

(2) The nature of the elevation of the eye and palpebral lobe: *Menomonia* has eyes somewhat elevated in position, but they are

definitely not stalked as in *Millardia*. This distinctly different position of the eyes is largely responsible for a third distinction between the two genera.

3. The nature of the facial suture: in *Menomonia* the suture is the normal open suture affording ready separation of free cheek and cranidium, as is usual with trilobite remains in these faunas. In a structure such as the stalked eye, however, the vertical parts of the suture must of necessity become tightly opposed or even fused to afford sufficient strength to the stalk. Consequently, during moulting the tight facial suture may not always give as readily as some other of the cephalic sutures, and, as in *Millardia*, the cranidium may retain the free cheeks. Pl. 4, fig. 42, shows a specimen in which the left suture has broken open, but the right one remained closed.

4. The character of the frontal border: Species of *Menomonia* possess a subtriangular to elliptical, prominent, convex frontal border, which in senile individuals may occupy nearly one-fourth the length of the cranidium. In *Millardia* the frontal border is a narrow, slightly arcuate vertical rim, which never becomes broader or more prominent. Resser (8) states that this difference in the frontal border "involves no altered structure and the gap between the two species is bridged by intermediate forms." However, he cites no such intermediate forms, and none are known to the author either among described species or among undescribed forms familiar to her. It is her opinion that there is a structural distinction between the frontal borders of *Menomonia* and *Millardia*.

Millardia and *Menomonia* are closely related genera and were correctly assigned to the same family by Walcott; but in view of the above listed differences, the author cannot regard them as the same genus.

The Norwoodidae have been augmented by a number of new species which have added greatly to the clarification of the relationships of the three genera now recognized in the family. Walcott's genus *Norwoodia* comprised a group of species that fall readily into three related but distinct genera, whose characteristics as evidenced by the genotypes, are shown in tabular form. The newly recognized genus, *Norwoodina*, genotype *N. tenera* (Walcott) is regarded as most similar to the ancestral genus of the family. *Norwoodella* and *Norwoodia* are considered more specialized in structure and are believed to have each branched off from the same parent genus, at present unknown, but occupying a stage of advancement from the ancestral form comparable to that reached by *Norwoodina*. In 1937 Resser (7) erected a new genus, *Whitfieldina*, for the species described by R. P. Whitfield as *Conocephalites? quadratus*. As this species is a true *Norwoodia*, very close to the genotype, *N. gracilis* Walcott, and was so recognized by G. O. Raasch (10) in 1935, the genus *Whitfieldina* automatically falls into synonomy (Resser, 8a).

Characteristics of the Genotypes of the Norwoodidae

Norwoodella

Outer surface smooth or very minutely granular.
Cranidium:
- Glabella always conical.
- Proportion of free cheek: glabella = $\frac{1}{3}$–$\frac{1}{5}$.
- Profile definitely low, smooth; furrows almost obsolete; glabella low; no ocular ridge.
- Frontal limb and border short.
- Posterolateral limbs narrow, medium length; stout, short genal spines
- Occipital spine short, stout.

Free cheek medium-sized, elongate-triangular; marginal furrow very faint.
Thorax having 10 segments, less distinct pleural furrows, no thoracic axial spines.
Pygidium having three segments and terminal portion; narrow, but definite marginal border; slightly greater obsolescence of furrows.
Genotype: *Norwoodella saffordi* (Walcott).
Other valid species: *N. simplex* (Walcott), *N. halli* Resser, *N. walcotti* Resser, *N. kingstonensis* Resser, *N. limbata* Resser.
Synonyms: *Norwoodella holstonensis* Resser = *Norwoodella walcotti* Resser; *Norwoodella declivis* Resser = *Norwoodella kingstonensis* Resser; *Plethometopus? tennesseensis* Resser = *Norwoodella* cf. *halli* Resser.

Norwoodia

Outer surface minutely granular.
Cranidium:
- Glabella with parallel sides, rounded front.
- Proportion of free cheek: glabella = approximately $\frac{1}{3}$.
- Profile moderately subdued; furrows present, faint and shallow; glabella slightly convex; faint ocular ridge.
- Frontal limb wide, transverse furrow deep.

Posterolateral limbs wide, heavy, long, with long slender genal spines.
Occipital spine variable.
Free cheek medium sized, oblongo-triangular; marginal furrow well-defined.
Thorax having nine segments, well-defined pleural furrows, long axial spine on ninth.
Pygidium having three segments and terminal portion; narrow, but definite marginal border; furrows fairly well-defined.
Genotype: *Norwoodia gracilis* Walcott.
Other valid species: *N. fillia* Lochman, n. sp. *N. quadrata* (Whitfield), *N. bonneterrensis* Lochman, n. sp.
Synonyms: *Norwoodia rogersvillensis* Resser = *Norwoodia gracilis* Walcott; *Norwoodia harlanensis* Resser is too poor for specific determination.

Norwoodina

Outer surface covered with small, distinct granules.
Cranidium:
Glabella subquadrate, slightly conical.
Proportion of free cheek: glabella = consistently 1:1 ±.
Profile strong; furrows well-defined though shallow; glabella convex; distinct ocular ridge.
Frontal limb and border convex, normal.
Posterolateral limbs and genal spine progressively increasing in size.
Occipital spine short, stout.
Free cheek small, short, triangular; marginal furrow well-defined.
Thorax having eight segments, well-defined, narrow pleural furrows, spines on 3, 5, 7 of axis.
Pygidium having 4 to 6 segments and terminal portion; extremely narrow marginal border; well-defined pleural furrows extending nearly out to margin.
Genotype: *Norwoodina tenera* (Walcott).
Other valid species: *N. tenera* var. *cuneifera* Lochman, n. var., *N. tunda* Lochman, n. sp., *N. appalachia* (Resser) (*N. ponderosa* (Walcott)), *N. katherina* Lochman.
Doubtful validity: *N. blainensis* Resser may = *N. tenera* (Walcott).
Synonyms: *Holcacephalus granulatus* Resser = *Norwoodina tenera* (Walcott).

CORRELATION OF THE FAUNA

Species in the Bonneterre Fauna

Ulrich's identification, 1928	Lochman's identification, 1940
Linguella leos Walcott.	*Lingulella modesta* Lochman, n. sp.
Obolus 2 undet. sp.	*Obolus matinalis* (Hall), *O. maesche* Lochman.
Micromitra alabamensis Walcott.	*Micromitra paucicostellae* Lochman, n. sp.
Micromitra sculptilis (Meek).	*Iphidella pannula maladensis* (Wa).
Acrotreta.	*Acrotreta ulrichi* Walcott.
Linnarssonella girtyi Walcott.[1]	Not present.
Hyolithes sp.	*Hyolithes primordialis* (Hall).
Plates of some chiton?	*Kinsabia varigata* Lochman, n. gen., n. sp.
Agnostidae of at least five species.	"*Agnostus*" *nordicus* Lochman, n. sp.
	Kormagnostus splendens Lochman, n. sp.
	Kormagnostus esterius Lochman, n. sp.
	Pseudagnostus mesleri (Resser).
Four species all closely allied to Appalachian and Cordilleran forms assigned to *Anomocarella* by Walcott.	*Brassicicephalus pulchellus* Lochman, n. gen. n. sp.
Maryvillia sp.	*Genevievella neunia* Lochman.
	Genevievella modesta Lochman, n. sp.
Hystricurus, 3 species.	*Blountia* sp.
	Coosella prolifica Lochman.
	Fragments of *Tricepicephalus* cranidia.
Menomonia cf. *calymenoides* (Whitfield).	*Menomonia calymenoides* (Whitfield).
Kingstonia, 2 n. sp.	*Kingstonia spicata* Lochman, n. sp.
	Kingstonia walcotti Resser.
Millardia.	*Millardia avitas* Walcott.
Norwoodia aff. *gracilis* Walcott.	*Norwoodia fillia* Lochman, n. sp.
"*Saratogia*" aff. *wisconsinensis* (Hall).	*Bonneterrina prima* Lochman.
"*Crepicephalus*" *texanus* (Shumard).	*Tricrepicephalus texanus* (Shumard).[2]
Crepicephalus comus Walcott.	*Tricrepicephalus paracomus* Lochman, n. sp.
Crepicephalus thoosa Walcott.	*Tricrepicephalus walcotti* Lochman.
Crepicephalus, 5 or 6 unnamed species.	*Tricrepicephalus davidi* Lochman, n. sp.
	Tricrepicephalus natalia Lochman, n. sp.
	Tricrepicephalus rex Lochman, n. sp.
	Meteoraspis delia Lochman, n. sp.

[1] The material from which *Linnarssonella girtyi* Walcott was described was collected from Dr. Ulrich's locality M22, which Dr. Josiah Bridge has subsequently been able to determine as belonging in the Davis formation (personal communication). The identification of the specimens is correct but they do not belong with the Bonneterre material.

[2] A few authentic cranidia of this species occur in Dr. Ulrich's collection, though none have been obtained from the author's collection.

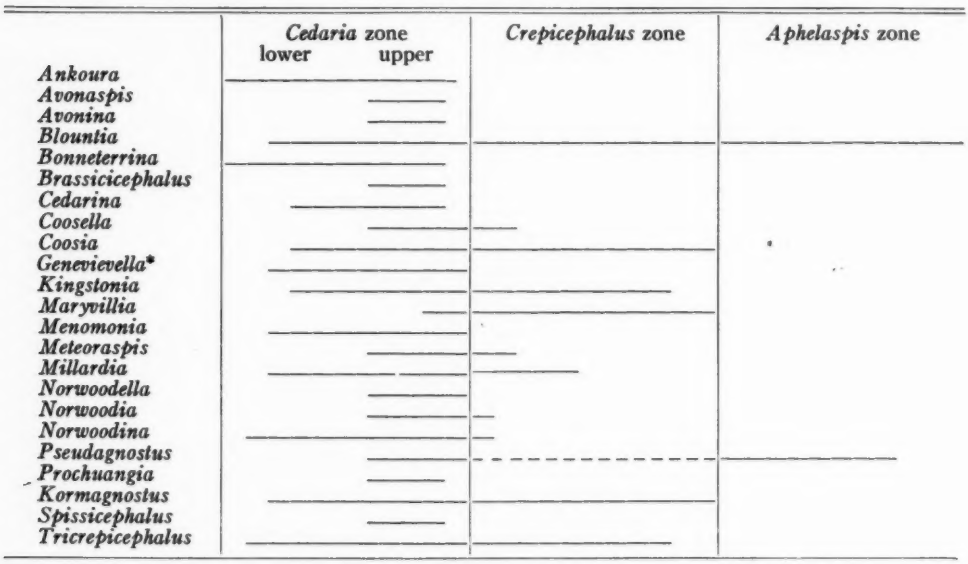
The Bonneterre fauna is a typical *Cedaria* assemblage and as such can be directly correlated with the *Cedaria* zone in the Eau Claire member of the Dresbach formation of the standard Upper Cambrian section of Wisconsin. As the fauna of the *Cedaria* zone was widespread over the North American continent and is now known from many localities in the United States, a satisfactory correlation of the Bonneterre dolomite with equivalent formations has been obtained (1, 9). The species in the Bonneterre fauna as identified by Dr. E. O. Ulrich in 1928 (14a), and by the author of the present paper are named in parallel columns on page 11.

The known distribution of the *Cedaria* faunal assemblage indicates that its members migrated into the interior of the continent from the south and southeast (via the Appalachian geosyncline) and from the northwest (via the Cordilleran geosyncline) with the advancing seas of the early Upper Cambrian. The Missouri region afforded an opportunity for the intermingling of the two faunal groups, which led to the development of an essentially cosmopolitan assemblage.

The Upper Cambrian sea east of the St. Francois Mountains apparently extended without major interruption towards the southeast into Tennessee. Toward the south and southwest the shallow sea stretched across southern Missouri, Arkansas, and Oklahoma into central Texas. Open connections also existed to the north and northwest, into Wisconsin and Minnesota,[1] and farther west across the Dakotas into the Cordilleran geosyncline.

[1] The apparent dissimilarity of faunas in the Missouri and Wisconsin regions, which led Ulrich in 1912 to postulate the presence of a land barrier between the two regions, has subsequently been found to have been caused by the incomplete state of knowledge of the several faunas at that date.

VERTICAL RANGE OF TRILOBITE GENERA IN THE BONNETERRE *Cedaria* ZONE



* *Genevievella* as exemplified by the genotype, *G. neunia* Lochman, occurs only in the *Cedaria* zone, whereas *Llanoaspis*, genotype *L. modesta* Lochman, which has been confused with *Genevievella* by Dr. Resser, is a guide fossil for the *Crepicephalus* zone. This is the correction to and explanation of Resser's statement (8b).

Recent stratigraphic studies in Texas and Montana have made possible the recognition of a two-fold subdivision of the *Cedaria* zone into an assemblage typical of early *Cedaria* time and one characteristic of late *Cedaria* time. The fauna of the lower Bonneterre beds is a typical late *Cedaria* assemblage and correlates directly with this upper subzone as developed in Texas and Montana. At present the majority of the Bonneterre species are known only from the late *Cedaria* subzone, and many of them only from the Missouri occurrence; but these geographic, and possibly even the stratigraphic restrictions, must be regarded as probably more apparent than real until the faunas of this zone have been thoroughly studied in other regions. A table showing the known vertical range of the Bonneterre trilobite genera is the only key of stratigraphic significance that can be offered at the present time.

SYSTEMATIC DESCRIPTIONS

CALCAREOUS ALGAE?
Plate 2, figures 4–6

Round, oval or sausage-shaped bodies with a slender round prolongation or stem at one end and a circular marking with a raised rim and light-colored center, resembling an aperture, at the other end. Stem two or three times the length of the body. Outer surface of body smooth, without markings. Preserved in dark-brown cryptocrystalline limestone, similar to that of the other fossils. Size ranges from small round bodies 0.5 mm in diameter to large elongate bodies over 1 mm in diameter and 3 mm in length.

Remarks.—These bodies are extremely abundant and occur at every locality in great numbers. The fact that they have a very definite structure leaves no doubt as to their organic origin, but their systematic position is uncertain. Their shape suggests that of either an immature or very primitive individual of the Pelmatozoa, but no trace of plates could be detected on the body or stem. However, stains were not used, and a more intensive study of the forms may yield more information as to their true structure and relationships.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at every locality

Repository.—Figured specimens, U.S.N.M. 98714, locality 82.22; unfigured specimens, U.S.N.M. 98715, locality 82.19; U.S.N.M. 98716, locality 82.18; U.S.N.M. 98717, locality 76.20.

Phylum PORIFERA
Genus CHANCELLORIA Walcott, 1920
CHANCELLORIA AURORA Lochman, n. sp.
Plate 2, figures 1–3

Specimens consisting of scattered skeletal spicules, usually 1 mm or less in width, and composed of four to seven side rays and one central vertical ray; the spicules originally siliceous with a minute axial canal in each ray; side rays may be either horizontal (90° from the vertical central ray) or slanting at (45° from central ray); central ray ranging from rectangular to septangular in shape to fit the bases of the side rays; side rays flat at base, then swelling out and gradually tapering to a point; longest rays observed 1.5 mm in length; sutures between rays loose, so that the spicule is frequently broken along these lines.

Remarks.—These sponge spicules occur at many localities but are much more abundant at some than at others. The sponge which they represent must have been an important and abundant member of the faunal community. These spicules are on an average smaller than those of the species of this genus in the *Crepicephalus* horizon of Texas and Montana.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at 76.36, 76.37, 76.38, 82.13, 82.20, 82.21, 82.25, 82.26.

Repository.—Holotype, U.S.N.M. 98712, locality 76.36; paratype, U.S.N.M. 98713, locality 76.34; unfigured paratype, U.S.N.M. 98713, locality 76.34.

Phylum ECHINODERMA
Subphylum PELMATOZOA
Class CRINOIDEA?
Plate 2, figures 13, 14

A large number of columnar joints and calyx plates are referred to an unknown genus of crinoid. The plates are irregularly hexagonal in shape, slightly elevated at the center, which bears a small circular boss, and average 3 to 5 mm in diameter. The stereom is 0.5 mm in thickness and shows no evidence of pore structures. The entire outer surface of the plates is covered with small tubercles arranged in rows parallel to the outer margin of the plate.

The stem joints are flat and rounded, 1 mm in thickness, with a small central circular canal and 10 symmetrically arranged oval canals around the periphery. No evidence as to the manner of articulation could be obtained.

One large plate in the collection is nearly circular, with a central depression surrounded by four evenly spaced rows of tubercles. It may represent a second species, or be merely a specialized anal plate of the same species.

The canal structure of the stem joints, and the lack of any pore structures in the plates suggests that this form belongs to the Crinoidea rather than the Cystoidea, to which many of the Cambrian Echinoderma plates have been commonly referred. However, the fragmentary condition of the material prevents a more exact determination of the nature of the specimens.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.25, 76.34, 76.37, 82.13, 82.19, 82.22, 82.23.

Repository.—Figured specimens, U.S.N.M. 98709, locality 82.19; unfigured stem joints, U.S.N.M. 98710, locality 76.25; unfigured plate, U.S.N.M. 98711, locality 82.22.

Phylum BRACHIOPODA
Order PALEOTREMATA
Family PATERINIDAE
Genus PATERINA Beecher, 1891
PATERINA MODESTA Lochman, n. sp.
Plate 1, figures 20, 21

Ventral valve small, 3 mm by 3 mm, subconical; beak low, near apex; homoeodeltidium not known, opening covered by it broad and low; reflected posterolateral margins very narrow. Dorsal valve small, 2.5 mm by 2.5 mm, subcircular, with straight posterior margin; beak small, near apex; opening covered by pseudochilidium, subcircular, small.

Outer shell layer shiny, covered only by fine, very regular, concentric growth ridges, spaced 10 to a millimeter. Inner layers not known.

Interior of valves not known.

Remarks.—This species is represented by numerous well-preserved dorsal and ventral valves, all of them small. The complete absence of any trace of radiating costellae sharply distinguishes the species from the majority of the previously described forms.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 82.11, 82.19, 82.12, 82.25, 76.29, 76.36, 76.24, 82.13, 82.14, 82.20.

Repository.—Holotype, ventral valve, U.S.N.M. 98668, locality 82.11; paratype, dorsal valve, U.S.N.M. 98669, locality 82.19; paratype, dorsal valve, not figured, U.S.N.M. 98670, locality 82.12.

Genus MICROMITRA Meek, 1873
MICROMITRA PAUCICOSTELLAE
Lochman, n. sp.
Plate 1, figures 23, 24

Ventral valve semicircular, a low cone; beak small but prominent, projecting beyond the nearly straight posterior margin; character of homoeodeltidium unknown. Dorsal valve semicircular, nearly flat, with a straight posterior margin; pseudochilidium not known.

Surfaces of valves covered with fine, regularly spaced, concentric growth ridges, crossed by low, narrow, bifurcating radiating costellae. On dorsal valve the costellae radiate over the entire surface, with sharpest definition along the lateral and anterior margins. On ventral valve the costellae, 5 or 6 in number, occur only on the middle portion of the shell.

Remarks.—This species is distinctive in the character of its surface markings. It appears to belong with the costellate *Micromitra* but represents a form in which the costellae are poorly defined. Some of the valves were identified by E. O. Ulrich in

1928 as *Micromitra sculptilis* (Meek), but the character of the costellae is quite different from that of the types of the latter species.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.29, 82.19, 82.21.

Repository.—Holotype, ventral valve, U.S.N.M. 98671, locality 82.21; paratype, dorsal valve, U.S.N.M. 98672, locality 76.29.

Genus IPHIDELLA Walcott, 1905

IPHIDELLA PANNULA MALADENSIS Walcott

Plate 1, figure 26

Trematis pannula WHITE, *1874*, U. S. Geol. and Geol. Survey W. 100th Mer., Rept., p. 6.
Micromitra (Iphidella) pannula maladensis (Walcott) WALCOTT, *1912*, U. S. Geol. Survey, Mon. 51, pt. I, p. 364 (for complete synonymy).

Original description of species:

Shell small, subcircular; ventral valve moderately convex; apex prominent, excentric; surface marked by a very fine network of oblique, raised lines, dividing it up into minute four-sided pore-like pits, which cause it to resemble, under a lens, finely woven cloth.
Diameter of the valve, about 3 mm.

Original description of variety:

Surface covered with elevated, sharp, distinct ridges that give it an irregular, honeycomb like appearance.
This form owes its varietal name to its occurrence near Malade, Idaho.

Remarks.—This species is represented by 11 sizable fragments of the shell and two complete exteriors of the ventral valve, all with the distinctive surface markings well preserved. Although this is the first record of the variety from the Upper Cambrian, the Bonneterre specimens are identical in all surface markings to those figured by Walcott from the type locality near Malade, Idaho; and until distinctive internal structures can be demonstrated, there appears no valid evidence for separating the Bonneterre forms from this species.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.24, 82.13, 82.14, 82.15.

Repository.—Plesiotype, ventral valve, U.S.N.M. 98673, locality 76.24.

Order ATREMATA

Superfamily OBOLACEA

Family OBOLIDAE

Subfamily OBOLINAE

Genus OBOLUS Eichwald, 1829

OBOLUS MAESCHE Lochman, n. sp.

Plate 1, figure 28

General form broad ovate, with the ventral valve broadly acuminate and the dorsal valve ovate; ventral valve averaging 11 mm in length by 9 mm in width; moderately convex with the convexity greatest in the posterior quarter of the shell. Shell composed of an outer layer and a number of inner lamellae, which are oblique to the outer layer over the greater portion of the valve. The outer layer marked with prominent concentric growth ridges and covered with a meshwork of punctations produced by an alternation of rows of pits of nearly uniform size with fine radiating striae. The inner layers covered with numerous radiating striae, several of which are more prominent than the rest, concentric lines, and irregularly scattered punctations.

Nothing known of the internal markings except traces in a ventral valve of a large, clubshaped visceral area, and the posterior portion of wide, straight vascular sinuses situated midway between the lateral margins and the visceral area.

Remarks.—Twenty specimens of *Obolus* valves, ranging in size from 2 to 11 mm in length are assigned to this species. In external shape the shells are similar to *Obolus matinalis*, but the peculiar surface markings readily differentiate it from that species.

Although *Westonia* is characterized by a reticulate surface, nothing exactly comparable to the kind found in *Obolus maesche* has previously been recorded in this genus, but as it is a feature that is visible only under high magnification it might easily have gone unnoticed on other species. It was first noted on small valves where higher magnification was used, and at first thought to be characteristic of the immature individuals, but subsequent examination of the surface of adult shells with equally high magnification showed it to be likewise present.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.21, 76.24, 76.25, 76.33, 76.34, 82.13,

82.14, 82.17, 82.20, 82.21, 82.22, 82.23, 82.25.

Repository.—Holotype, dorsal valve, U.S.-N.M. 98674, locality 82.13.

OBOLUS MATINALIS (Hall)
Plate 1, figure 25

Orbicula prima OWEN, *1852*, Rept. Geol. Survey Wisconsin, Iowa and Minnesota, p. 583.
Obolus matinalis (Hall) WALCOTT, *1912*, U. S. Geol. Survey, Mon. 51, pt. 1, p. 400 (for synonomy to date).
Obolus matinalis (Hall) BRIDGE, *1932*, Univ. Texas, Bull. 3232, pl. 2, figs. 14–16.

Original description:

Shell obliquely depressed, conical; circumference nearly circular or slightly quadrangular; concentric and somewhat subquadrangular striae. 4/16 to 5/16 of an inch in diameter.

Remarks.—Several of the valves retain most of the dark-brown exterior layer showing the concentric ridges and radiating striae of the surface very plainly. Good interiors of the shells are rare. An interesting feature of the specimens is the many well-preserved worm borings on the inner layers of the valves.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.20, 76.21, 76.22, 76.29, 76.34, 82.13, 82.22.

Repository.—Plesiotype, ventral valve, U.S.N.M. 98675, locality 76.22; specimen not figured, U.S.N.M. 98676, locality 76.21.

Subfamily LINGULELLINAE
Genus LINGULELLA Salter, 1866

LINGULELLA MODESTA Lochman, n. sp.
Plate 1, figure 22

Shell small, elongate-ovate in outline, with a regular convexity reaching 0.75 mm at center of valve. Dorsal valve not known.

EXPLANATION OF PLATE 1

FIGS. *1, 2—Dicellomus fiestus* Lochman, n. sp. *1*, Paratype, ventral valve, U.S.N.M. 98685, ×10, loc. 76.37. *2*, Holotype, fragmentary dorsal valve, U.S.N.M. 98684, ×10, loc. 82.17 (p. 19)

3–7—Linnarssonella transversa Walcott. *3*, Plesiotype, interior ventral valve, U.S.N.M. 98694, ×8, loc. 76.24. *4*, Plesiotype, interior ventral valve, U.S.N.M. 98693, ×16, loc. 82.13. *5*, Plesiotype, ventral valve, exterior, U.S.N.M. 98694, ×16, loc. 76.24. *6*, Plesiotype, ventral valve, exterior, U.S.N.M. 82.13, ×16, loc. 82.13. *7*, Plesiotype, interior ventral valve showing apical callosity, U.S.N.M. 98693, ×16, loc. 76.24. (p. 21)

8—Dicellomus politus (Hall). Plesiotype, dorsal valve showing position of central muscle scars, U.S.N.M. 98686, ×6, loc. 82.17. (p. 19)

9–12—Dicellomus appalachia Walcott. *9*, Plesiotype, interior of dorsal valve, well preserved, U.S.N.M. 98682, ×6, loc. 82.13. *10, 11*, Exteriors, dorsal and ventral valve, U.S.N.M. 98683, ×4, loc. 91.9. *12*, Plesiotype, exfoliated ventral valve to show alternating costellae, U.S.N.M. 98681, ×4, loc. 82.15. (p. 18)

13–17—Acrotreta ulrichi Walcott. *13–15*, Plesiotype, perfect ventral valve, shell partly exfoliated; *13*, top view, *14*, lateral view, *15*, posterior view, U.S.N.M. 98690, ×10, loc. 76.24. *16*, Plesiotype dorsal valve, interior, U.S.N.M. 98692, ×6, loc. 76.21. *17*, Plesiotype, ventral valve, interior, U.S.N.M. 98691, ×6, loc. 76.37. (p. 20)

18, 19—Dicellomus walcotti Lochman, n. sp. *18*, Holotype, dorsal valve, showing partly covered muscle scars, the inner shell lamellae with radiating costellae of variable strength, and part of outer shell surface on left side, U.S.N.M. 98687, ×10, loc. 76.21. *19*, Paratype, interior, dorsal valve, showing shape of central muscle scars, U.S.N.M. 98688, ×10, loc. 82.22. (p. 20)

20, 21—Paterina modesta Lochman, n. sp. *20*, Holotype, ventral valve, U.S.N.M. 98668, ×8, loc. 82.11. *21*, Paratype, dorsal valve, U.S.N.M. 98669. ×8, loc. 82.19. (p. 14)

22—Lingulella modesta Lochman, n. sp. Holotype, ventral valve, U.S.N.M. 98677, ×6, loc. 82.22. (p. 16)

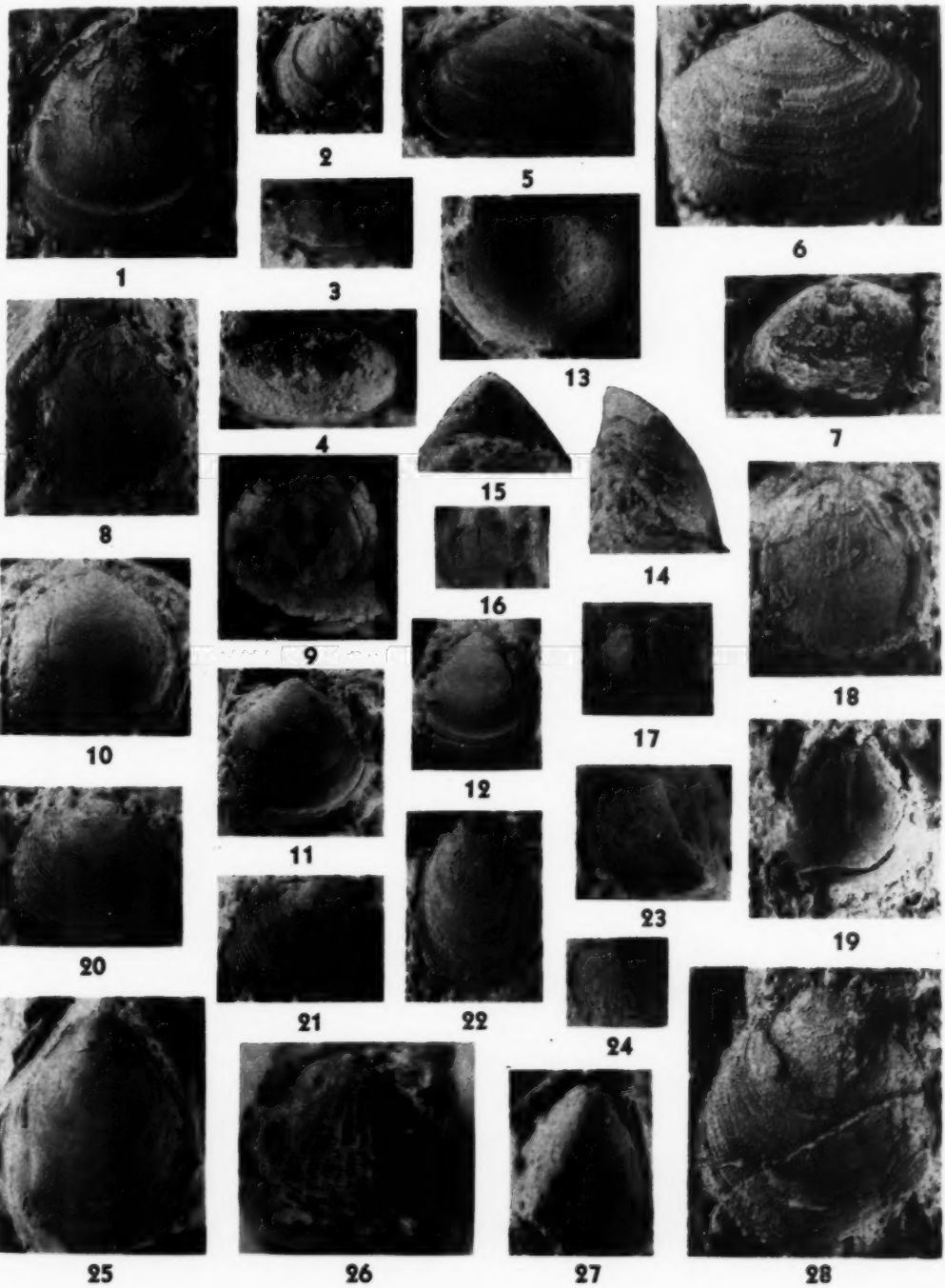
23, 24—Micromitra paucicostellae Lochman, n. sp. *24*, Holotype, ventral valve showing characteristic surface markings, U.S.N.M. 98671, ×8, loc. 82.21. *23*, Paratype, broken dorsal valve, showing weaker costellae, U.S.N.M. 98672, ×8, loc. 76.29. (p. 14)

25—Obolus matinalis (Hall). Plesiotype, ventral valve showing characteristic shape and inner surface costellae, U.S.N.M. 98675, ×3, loc. 76.22. (p. 16)

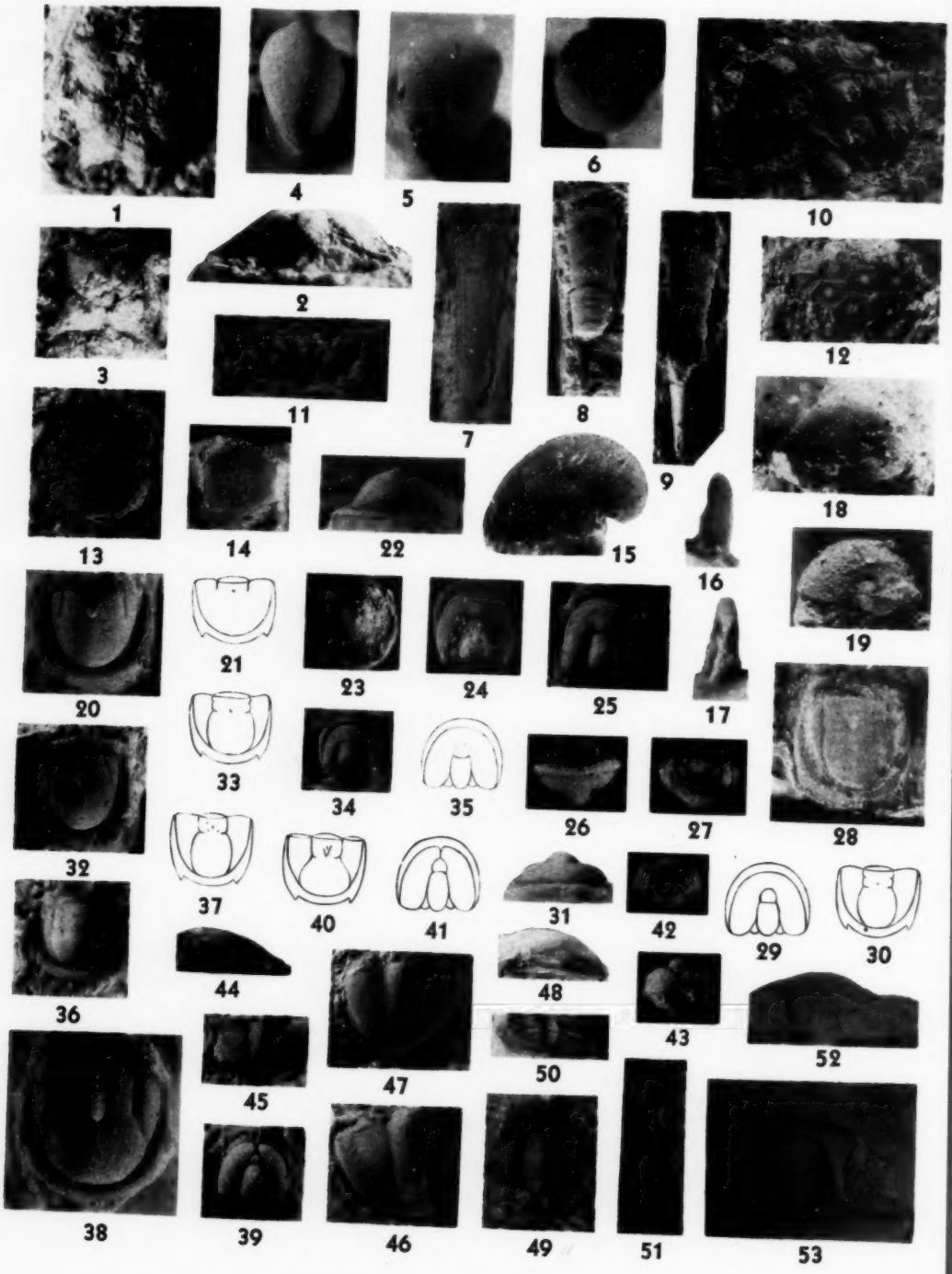
26—Iphidella pannula maladensis (Walcott). Plesiotype, well preserved ventral valve showing surface ornamentation diagnostic of the variety, U.S.N.M. 98673, ×10, loc. 76.24. (p. 15)

27—Lingulella perattenuata (Whitfield). Plesiotype, ventral valve with beak broken, U.S.N.M. 98680, ×3, loc. 76.20. (p. 18)

28—Obolus maesche Lochman, n. sp. Holotype, dorsal valve, U.S.N.M. 98674, ×3, loc. 82.13. (p. 15)



Lochman, Upper Cambrian Fossils



Lochman, Upper Cambrian Fossils

Outer surface of shell slightly dulled, marked by numerous narrow concentric growth ridges and fine radiating costellae; inner shell layers very shiny, with concentric growth ridges and radiating costellae, of which the latter are more prominent; on anterior third of valve, rows of minute punctae appear between the growth ridges; on innermost shell layer the same markings are present, but the punctae are fewer and much coarser.

Remarks.—This species is a small but apparently rather widely distributed form in the *Cedaria* zone of the United States. In its shape and surface ornamentation it is comparable to two of Walcott's species. The Middle Cambrian *Lingulella leos* (Walcott), to which several specimens of the Bonneterre species were referred by E. O. Ulrich in 1928, differs in its more slender elongate shape with an acuminate posterior margin, and in the great abundance of coarse punctae on the innermost layer of the shell. *Lingulella similis* (Walcott) from the Franconian of Wisconsin also has a more acuminate shape rather than the symmetrical

---

EXPLANATION OF PLATE 2

FIGS. *1–3—Chancelloria aurora* Lochman, n. sp. *1, 2*, Holotype; top and side view of large spicule with seven side rays, U.S.N.M. 98712, ×20, loc. 76.36. *3*, Paratype, top view of small spicule with four side rays, U.S.N.M. 98713, ×20, loc. 76.34. (p. 13)

4–6—Calcareous algae? *5, 6*, Side and top views of large body from which stem is broken, U.S.N.M. 98714, ×10, loc. 82.22. *4*, Side view of small body showing base of stem, U.S.N.M. 98714a, ×10, loc. 82.22. (p. 13)

7—Hyolithes avonensis Lochman, n. sp. Holotype, U.S.N.M. 98707, ×3, loc. 76.21. (p. 23)

8, 9—Hyolithes primordialis (Hall). Plesiotype, U.S.N.M. 98708, ×3, loc. 82.19. (p. 23)

10, 11—Kinsabia varigata Lochman, n. gen., n. sp. *10*, Holotype, largest fragment, U.S.N.M. 98719, ×3, loc. 76.36. *11*, Paratype, smaller fragment showing marginal arrangement of plates, U.S.N.M. 98720, ×3, loc. 82.12. (p. 51)

12—Merostome fragment, U.S.N.M. 98718, ×5, loc. 76.20. (p. 52)

13, 14—Crinoidea? plates, U.S.N.M. 98709, ×3, loc. 82.19. (p. 14)

15–17—Pelagiella? semispira Lochman, n. sp. Holotype, U.S.N.M. 98706; *15*, side view showing longitudinal ridges, ×12; *16*, anterior view, ×6; *17*, posterior view, ×6, loc. 76.21. (p. 22)

18, 19—Pelagiella bridgei Lochman, n. sp. *18*, Holotype, large shell showing surface ornamentation, U.S.N.M. 98704, ×20, loc. 82.19. *19*, Paratype, small shell showing protoconch, U.S.N.M. 98705, ×20, loc. 82.13. (p. 22)

20–22—"Agnostus" nordicus Lochman, n. sp. *20, 22*, Holotype; dorsal and posterior views of a well-preserved pygidium, U.S.N.M. 98695, ×5, loc. 76.25. *21*, Sketch to show salient characteristics of pygidium. (p. 23)

23–31—Kormagnostus splendens Lochman, n. sp. *28*, Holotype, a large pygidium, U.S.N.M. 98700, ×6, loc. 82.13. *25, 31*, Paratype, an associated cephalon, U.S.N.M. 98700a, ×5, loc. 82.13. *23–27*, Paratype, an immature enrolled individual, U.S.N.M. 98701, ×10, loc. 76.34. *23, 24*, Dorsal views of pygidium and cephalon; *26*, anterior view; *27*, thoracic view. *29, 30*, Sketch to show salient characteristics of cephalon and pygidium of the species. (p. 25)

32–35—Kormagnostus esterius Lochman, n. sp. *32*, Holotype, a large pygidium, U.S.N.M. 98697, ×5, loc. 82.19. *34*, Paratype, dorsal view of a small cephalon, U.S.N.M. 98698, ×5, loc. 76.25. *33, 35*, Sketch to show salient characteristics of pygidium and cephalon of the species. (p. 24)

36, 37—Kormagnostus senatus Lochman, n. sp. *36*, Holotype, dorsal view of pygidium, U.S.N.M. 98696 ×6, loc. 76.25. *37*, Sketch to show salient characteristics of pygidium. (p. 25)

38–43—Pseudagnostus mesleri (Resser). *38, 39*, Plesiotypes, dorsal views of a well-preserved pygidium and cephalon, U.S.N.M. 98703, ×10, loc. 76.20. *40, 41*, Sketch to show salient characteristics of the species. *42, 43*, Plesiotype, thoracic and anterior views of an immature enrolled individual, U.S.N.M. 98703a, ×10, loc. 76.20. (p. 26)

44–46—Blountia sp. undet. 1. *44, 46*, Side and dorsal views of a large pygidium, U.S.N.M. 98725, ×2, loc. 76.22. *45*, Dorsal views of a small perfect pygidium, U.S.N.M. 98724, ×5, loc. 76.20. (p. 41)

47, 48—Blountia sp. undet. 2. Dorsal and side views of a complete pygidium showing the worn inner surface, U.S.N.M. 98726, ×1½, loc. 82.13. (p. 41)

49—Bonneterrina prima Lochman. Plesiotype, a small cranidium, U.S.N.M. 98732, ×3, loc. 76.21. (p. 43)

50–53—Cedarina vale Lochman, n. gen., n. sp. *52, 53*, Holotype; side and dorsal views of cranidium, U.S.N.M. 98734, ×3, loc. 76.21. *50*, Paratype, a small pygidium, U.S.N.M. 98734a, ×3, loc. 76.21. *51*, Paratype, free cheek, U.S.N.M. 98735, ×3, loc. 76.37. (p. 37)

ovate form of *Lingulella modesta*, n. sp.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.21, 76.22, 76.29, 76.37, 82.20, 82.22, 82.25.

Repository.—Holotype, ventral valve, U.S.N.M. 98677, locality 82.22; paratypes, ventral valves, unfigured, U.S.N.M. 98678, 98679, localities 76.21, 76.29.

LINGULELLA PERATTENUATA (Whitfield)
Plate 1, figure 27

Lingulepis perattenuatus WHITFIELD, *1877*, U. S. Geog. and Geol. Survey of Rocky Mtn. Region, Paleontology of the Black Hills, Prel. Rept., p. 9.

Lingulella perattenuata (Whitfield) WALCOTT, *1912*, U. S. Geol. Survey, Mon. 51, pt. I, pp. 523–524.

Original description:

Shell spatulate or elongate-ovate, becoming acutely pointed toward the beak; sides below the middle of the length of the ventral valve rounded; front margin very regularly curved; cardinal slopes straight, or sometimes slightly convex; greatest width a little more than half the length of the ventral valve and sometimes nearly two-thirds as great. Surface of the ventral valve depressed convex, very slightly subangular along the middle above the lower third of the length, and a little more distinctly so in the upper part. Apex scarcely truncate. Dorsal valve considerably shorter than the ventral, broadly truncated at the upper end, the line of truncation being distinctly arched. Surface evenly convex. Structure of the surface of the shell polished, with fine, somewhat lamellose lines of growth.

Remarks.— The Bonneterre specimens agree most closely with the types in shape, size and exterior markings, but their identity cannot be regarded as unquestionable, as no internal casts of the ventral valve occur in the collection. Two good interiors of dorsal valves show the two narrow vascular sinuses running parallel and close together on the posterior half of the valve, and then diverging gradually along the anterior half; and a prominent median ridge situated between the sinuses.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.24, 82.19.

Repository.—Plesiotype, ventral valve, U.S.N.M. 98680, locality 76.20.

Subfamily BICIINAE
Genus DICELLOMUS Hall, 1873
DICELLOMUS APPALACHIA Walcott
Plate 1, figures 9–12

Dicellomus appalachia WALCOTT, *1905*, U. S. Nat. Mus., Proc., vol. 28, p. 314.

Discellomus appalachia Walcott WALCOTT, *1912*, U. S. Geol. Survey, Mon. 51, pt. I, p. 572.

Dicellomus appalachia Walcott BUTTS, *1926*, Alabama Geol. Sur., Special Rept. 14, pl. 8, figs. 10, 11.

Original description:

This shell has been identified with *D. politus* in the preliminary studies of the genus *Dicellomus*. I find that while it has the same type of shell structure and general form, it differs in being less elongate proportionally, and in the details of the form and positions of the muscle scars and vascular markings of the interior of the valve; it differs in the latter respect from *D. nanus*. The outer thin layer has a dull, slightly roughened surface that is minutely punctate. When the outer layer is exfoliated the surface of the layer beneath is highly polished and marked by exceedingly fine radiating striae and concentric striae and lines of growth. The interior of the dorsal valve shows the larger central muscle scars with the minute anterolateral scars almost in contact with them. A composite scar shows the separate points of attachment of the transmedian, outside, and middle lateral scars. The variation in the length of the visceral cavity of the dorsal valve is very great.

The species occurs in great abundance in both limestones and shales. It is the representative of the widely distributed *D. politus* in the interior of the continent.

Remarks.—Several hundred well-preserved specimens of this species, including many interior casts of both dorsal and ventral valves, occur in the collection. The shells are either broadly ovate or nearly circular in shape, with the width sometimes exceeding the length. The ventral valves average 4 mm by 4 mm and the dorsal valves 3.5 mm by 4 mm. The largest valve, a dorsal valve, measures 6.5 mm by 6.5 mm.

The excellent preservation of these small and fragile valves is quite remarkable, as not only is the shell material complete but the original color markings are frequently present.

The type of alternating costellae on the inner layers of the valve, mentioned by Walcott as characteristic of *D. politus*, has also been noted on valves showing the internal markings of *D. appalachia*, and so

cannot be considered as a diagnostic specific character.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.24, 76.25, 76.33, 76.37, 82.13, 82.15, 82.17, 82.18, 82.19, 82.22, 82.23, 91.9.

Repository.—Plesiotype, ventral valve, U.S.N.M. 98681, locality 82.15; plesiotype, dorsal valve, U.S.N.M., 98682, locality 82.13; plesiotypes, exteriors, U.S.N.M. 98683, locality 91.9.

DICELLOMUS FIESTUS Lochman, n. sp.
Plate 1, figures 1, 2

General form of ventral valve elongate, ovate, moderately convex, length 3.5 mm, width 3 mm; dorsal valve ovate, moderately convex, dimensions approximately 2.5 mm by 2.5 mm. Outer surface marked with regularly spaced concentric ridges, inner shell layers with a shiny surface and covered with fine radial costellae and very fine punctations, as well as concentric ridges.

Interior of the ventral valve showing a central elongate visceral area of shape similar to that of *D. appalachia* but confined to the posterior one-third of the valve; main vascular sinuses prominent, straight, and situated well in from the lateral margins; posterior muscle scars large, composite, oval and situated at the posterolateral margins; central muscle scars large, transverse, lying between the anterior portion of the visceral area and the vascular sinuses.

Interior of the dorsal valve showing medium-sized oval central muscle scars lying close together and well within the posterior half of the shell; the minute anterolateral scars lying below them; visceral area short and situated within the posterior third of the valve; composite muscle scars large and situated near beak; main vascular sinuses narrow, extending beyond the central muscle scars to the center of the valve parallel to each other, and then diverging slightly; a sharp, thin median septum lying between the central muscle scars along the posterior half of the valve.

Remarks.—*D. fiestus* is distinguished from the described species by the pronounced posterior position of the visceral area and central muscle scars. The species is also represented in the Conasauga shale of Alabama by the several dorsal valves that were doubtfully referred to *D. appalachia* by Walcott (12).

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.24, 76.33, 76.37, 82.14, 82.18, 82.19, 82.22, 82.25.

Repository.—Holotype, dorsal valve, U.S.N.M. 98684, locality 82.17; paratype, ventral valve, U.S.N.M. 98685, locality 76.37; unfigured paratype, dorsal valve, U.S.N.M. 98685, locality 76.37.

DICELLOMUS POLITUS (Hall)
Plate 1, figure 8

Lingula polita HALL, *1861*, Rept. Supt. Geol. Survey Wisconsin, p. 24.
Dicellomus politus (Hall) WALCOTT, *1912*, U. S. Geol. Survey, Mon. 51, pt. I, pp. 575–578 (for complete synonomy).

Original description:

Shell small, short ovate, the greatest width near the front, which is broadly rounded; beaks obtusely rounded; valves moderately convex, with prominent umbones. Surface glabrous, or marked by very fine concentric lines of growth.

The interior of the ventral valve shows a distinct spatulate muscular impression in the centre, with raised margins, and fainter impressions at the sides. There is an obtuse dental process on each side of the rostral cavity.

This species differs from *L. prima* in the prominence of the umbones, and in being destitute of the lamellose concentric lines of growth. The shell was referred by Dr. D. D. Owen to *Obolus*, but I am unable to find satisfactory evidence of the features of *Obolus;* neither do the characters correspond with true *Lingula.*

Remarks.—The species is much less common in the collection than *D. appalachia* Walcott. The number of ventral valves is large, but positively identified dorsal valves have been found only at locality 82.17. They appear identical to the poorly preserved interiors figured by Walcott, showing central muscle scars that are medium-sized, oval in shape and crowded close to the median septum in the center of the valve. As a rule the valves average about 2 mm larger than those of *D. appalachia*, a feature which undoubtedly is responsible for the greater emphasis being placed on the alternating striae in this species.

All *Dicellomus* valves of which only the exteriors are known have been grouped together under *Dicellomus* sp. undet. Shells

of the genus have been obtained from every Bonneterre fossil locality.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.22, 76.24, 76.25, 76.33, 76.37, 82.13, 82.17, 82.18, 82.19, 91.9.

Repository.—Plesiotype, dorsal valve, U.S.N.M. 98686, locality 82.17.

Dicellomus walcotti Lochman, n. sp.
Plate 1, figures 18, 19

Ventral valve not known. Dorsal valve subcircular or broadly ovate, moderately convex; averaging 2.5 mm by 2.5 mm; outer surface thick, dull, covered with concentric growth ridges; inner shell layers thin, numerous, oblique to outer, and covered with fine radiating costellae and numerous small punctae as well as concentric ridges.

Interior of dorsal valve with narrow median septum extending one-half length of shell, bounded by narrow main vascular sinuses, which extend parallel anteriorly to center of valve, then diverge abruptly and fade out before reaching anterior margin; central muscle scars narrow, elongate, crescentiform, situated in middle of valve; small anterolateral scars lying just in front of them near sinuses; composite muscle scars large, elongate, situated well out near posterior lateral margin.

Remarks.—This species appears to be a rather common form in rocks of this horizon. It is known from the Eau Claire member of the Dresbach formation of Wisconsin, but was long grouped with *D. politus* (Hall). Dr. Ira Edwards, Milwaukee Public Museum, first recognized the species as new while restudying the brachiopods of the Wisconsin Upper Cambrian. He has very kindly given the author permission to describe it in this paper.

Ten interiors of dorsal valves in the Bonneterre collections can be positively assigned to the species, but no distinctive ventral valves have been obtained. Undoubtedly it is represented among the many exteriors which cannot be specifically identified.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.24, 76.37, 82.18, 82.22.

Repository.—Holotype, dorsal valve, U.S.N.M. 98687, locality 76.21; paratype, interior of dorsal valve, U.S.N.M. 98688, locality 82.22; unfigured paratype, dorsal valve, U.S.N.M. 98689, locality 76.37.

Order Neotremata
Family Acrotretidae
Genus Acrotreta Kutorga, 1848
Acrotreta ulrichi Walcott
Plate 1, figures 13–17

Acrotreta ulrichi Walcott, *1908*, Smithsonian Misc. Coll., vol. 53, no. 3, pp. 96–97.

Acrotreta ulrichi Walcott Walcott, *1912*, U. S. Geol. Survey, Mon. 51, pt. I, p. 714.

Original description:

This species is founded on a single specimen of a finely preserved ventral valve. The outline of the aperture is nearly circular, except for a short transverse portion beneath the false area; surface moderately convex, with the apex curving and ending beyond the posterior margin so that the minute foraminal aperture opens backward; a small false area is indicated by a slight incurving at the cardinal angles; the area is without traces of a median furrow.

Surface of shell marked by very fine, concentric striae and lines of growth. Length and width of aperture 2 mm, convexity of ventral valve 1 mm.

Supplementary description:

General form of the shells ovate; ventral valve transversely ovate in outline, with a short, straight posterior margin directly in front of the false area; valve strongly convex, convexity measuring 1 to 1.2 mm; maximum convexity occurring in the median line of valve, with the surfaces sloping gently down to the apex and the anterior margin and more abruptly to the posterior margin. Apex of valve curving down and extending beyond posterior margin, causing the false area to slope backward towards posterior margin, a distinctive feature of the species; false area defined by a slight incurving of the cardinal slopes to form a flattened triangular area without trace of a median furrow; pedicle aperture small, circular in shape, opening backward into valve.

Dorsal valve subcircular in outline, moderately convex, with greatest convexity at the umbo; small beak curving down upon posterior margin; a shallow depression extending along the middle of valve from umbo nearly to anterior margin.

Ventral valve 2.5 mm long by 3 mm wide; dorsal valve 2 mm long by 2 mm wide.

Shell composed of several thin lamellae,

arranged somewhat obliquely to the outer surface and marked with numerous fine, regular concentric striae, which continue across the false area; innermost surface of the shell shiny and covered with many fine concentric ridges, slightly wavy in character, and with innumerable short, fine, irregular dark lines.

Interior of the ventral valve showing large deep semicircular scar of the apical callosity, with a small circular scar left by the broken end of the pedicle tube just posterior to the callosity; the large oval cardinal muscle scars lie posterior to and on each side of the apical callosity; main vascular sinuses forming strong rounded ridges, which originate very close to posterior margin, extend forward parallel to each other between the cardinal muscles and the apical callosity, round out slightly to accommodate the latter, and then suddenly diverge at an angle of 75°, continuing their course in a straight line nearly to the anterior margin; in anterior half of valve the ridges gradually flatten out, but retain the same width to their termination.

Interior of dorsal valve marked by a prominent median septum extending anteriorly half the length of valve; vascular sinuses broad and parallel to the median septum; oval cardinal muscle scars of medium size, located on each side of median septum close to posterior margin.

This species is represented by a large number of well-preserved specimens of both valves. It is possible that the internal markings of *A. ulrichi* Walcott may be found to be different from those of the specimens of the Bonneterre, when more material from the type locality has been obtained; but because the exteriors are identical, they can only be considered the same at present.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.24, 76.33, 76.37, 82.15, 82.16, 82.20, 82.22, 82.23, 82.24, 82.25.

Repository.—Plesiotype, ventral valve, U.S.N.M. 98690, locality 76.24; plesiotype, interior, ventral valve, U.S.N.M. 98691, locality 76.37; plesiotype, interior, dorsal valve, U.S.N.M. 98692, locality 76.21; unfigured dorsal valves, U.S.N.M. 98692, 98691, locality 76.21, 76.37; unfigured ventral valves, U.S.N.M. 98691, locality 76.37.

Genus LINNARSSONELLA Walcott, 1902
LINNARSSONELLA TRANSVERSA Walcott
Plate 1, figures 3–7

Linnarssonella transversa WALCOTT, *1908*, Smithsonian Misc. Coll., vol. 53, no. 3, p. 92.
Linnarssonella transversa Walcott WALCOTT, *1912*, U. S. Geol. Survey, Mon. 51, pt. 1, p. 670.

Original description:

This is a small shell that at first sight suggests *L. modesta;* it differs from that species in the valves being more convex, transverse instead of circular, and in having stronger concentric striae, and, in some instances, radiating striae. A few fragments of the interior of the dorsal valve indicate that the main vascular sinuses are well out toward the outer margin, and that small circular depressions occur on each side of the median line, very much as in the dorsal valve of *L. girtyi:* and two small central muscle scars midway between the posterior and anterior margins of the valve. *L. transversa* differs from all other species of the genus known in its transverse outline. The average shell has a width of 2 mm, with a length of from 1.5 to 1.7 mm.

Supplementary description:

Interior of ventral valve with poorly defined main vascular sinuses, the ridges acquiring prominence only near the beak, and from there extending as low elevations well out toward the lateral margins; pedicle tube small, circular, lying far forward near the posterior margin; anterior to tube a medium-sized, roughly pentagonal visceral area, which is clearly delineated by the two sinuses on the sides and by a low V-shaped ridge anteriorly; cardinal muscle scars large, oval in outline, lying directly on outer edge of each sinus.

Remarks.—The species is represented in the collection by over thirty specimens, including both dorsal and ventral valves. The majority of the shells are well preserved, several of them having retained most of the shell layers. Impressions of the internal markings of the ventral valve are well preserved on several smooth limestone molds.

The valves are distinguished by their striking transverse outline, their strong convexity, especially at the umbo, and their small dimensions. All the valves in the collection are consistent in size, averaging between 2 and 3 mm in width and 1.5 or 2 mm in length, with a convexity of nearly 0.5 mm. Each valve has a distinct but shallow median depression running from the umbo to the anterior margin. None of the ventral

valves has a perfect beak or false area preserved, but the beak appears to curve far down and over the area nearly to the posterior margin. In dorsal valves the small pointed beak can be seen curving down upon the posterior margin.

The outer shell layer is dull and marked simply by many fine concentric growth lines. The inner layers of the shell have a shiny surface and usually are marked not only by fine concentric ridges but also by fine radiating striae.

A mold of the interior of a dorsal valve exhibits certain of the internal markings quite well. Extending down the center of the valve is a faint shallow depression, marking the line of the median septum. Two medium-sized oval central muscle scars lie near the middle of the valve, with one small anterolateral muscle scar appearing just to the right of the median septum below the central muscle scar.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.24, 76.29, 82.12, 82.13, 82.14, 82.19, 82.22.

Repository.—Plesiotypes, interior ventral valves, U.S.N.M. 98694, 98693, localities 76.24, 82.13; plesiotypes, exterior ventral valves, U.S.N.M. 98694, 98693, localities 76.24, 82.13.

Phylum MOLLUSCA
Class GASTROPODA
Subclass PROSOBRANCHIA
Order ARCHAEOGASTROPODA
Family CYRTOLITIDAE
Genus PELAGIELLA Matthew, 1895

PELAGIELLA BRIDGEI Lochman, n. sp.
Plate 2, figures 18, 19

Shell small, planispiral, loosely coiled; regularly arcuate from apex to aperture, making 1¼ volutions; spire depressed; protoconch globular in shape, delineated from rest of shell by a stricture; whorls subelliptical in section, without a keel, rounded on dorsal and angular on ventral side; aperture elliptical, with a shallow median sinuosity.

Surface covered with fine concentric growth lines, which are regular near the apex, but become crowded together along the dorsal edge of aperture in following the apertural sinuosity; and with several low longitudinal ridges along middle of whorl.

Maximum diameter of body whorl, 0.5 mm.

This species is represented in the collection by many individuals, ranging in size from 0.5 mm. to 1.5 mm, and affording an excellent opportunity for studying the development of the shell. The outer surface ornamentation is nearly perfect on several of the specimens.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.34, 82.13, 82.18, 82.19, 82.22.

Repository.—Holotype, U.S.N.M. 98704, locality 82.19; paratype, U.S.N.M. 98705, locality 82.13; two unfigured paratypes, U.S.N.M. 98705, locality 82.13.

PELAGIELLA? SEMISPIRA Lochman, n. sp.
Plate 2, figures 15–17

Shell a small high cone, strongly but not quite symmetrically recurved toward the narrow anterior side, forming an open coil of one-half volution; apex smoothly rounded; cone subelliptical in outline, rounded on posterior side, narrowing to an acute angle on anterior side; aperture with a very shallow median sinuosity.

Surface showing faint traces of concentric ridges from apex to aperture on lateral and dorsal sides, narrowing rapidly on the ventral edge; crossing them on posterior half of shell a series of low arcuate longitudinal folds extends from apex to aperture.

Average diameter of body whorl 1.5 mm.

Remarks.—This species is about equally as abundant as *Pelagiella bridgei* in the Bonneterre material. It is difficult to place the species exactly as to generic position, for though it shows a tendency to the same type of coiling found in *Pelagiella*, it is not coiled closely as is the genotype and species commonly referred to the genus.

It is undoubtedly congeneric with the form described as *Platyceras transversum* by Matthew in 1899 from the Etcheminian fauna of Smith Sound, Newfoundland. In view of the present extremely limited knowledge of Cambrian gastropods, it is considered advisable to refer the species to *Pelagiella?*, until additional material should prove whether or not it is a valid new genus.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at locality 76.21.

Repository.—Holotype, U.S.N.M. 98706, locality 76.21; paratypes, U.S.N.M. 98706, locality 76.21.

Subclass EUTHYNEURA
Order OPISTHOBRANCHIA
Suborder PTEROPODA
Family HYOLITHIDAE
Genus HYOLITHES Eichwald, 1840
HYOLITHES AVONENSIS Lochman, n. sp.
Plate 2, figure 7

Shell elongate, tapering gradually to a blunt apex; 10 mm long by 3.5 mm wide across the aperture; one side slightly convex, the other strongly arcuate; the slightly convex side marked along each margin by a furrow and a ridge running the entire length of the shell parallel to the margin; lip of aperture on this side elevated and rounded; surface of other side unknown. Inner surface of the shell marked by longitudinal striae and thick transverse ridges.

Remarks.—This form has been described as a new species although only two specimens are present in the collection because its surface markings and shell structure are quite distinctive from any described species. It is apparently a much rarer form in the fauna than *Hyolithes primordialis*.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.25.

Repository.—Holotype, U.S.N.M. 98707, locality 76.21.

HYOLITHES PRIMORDIALIS (Hall)
Plate 2, figures 8, 9

Theca primordialis HALL, *1861*, Geol. Survey Wisconsin, Ann. Rpt. Progress, p. 48.
Hyolithes primordialis (Hall) WALCOTT, *1899*, U. S. Geol. Survey, Mon. 32, p. 454 (for synonomy to date).
Hyolithes primordialis (Hall) WALCOTT, *1916*, Smithsonian Misc. Coll., vol. 64, p. 256, pl. 37, fig. 1.

Original description:

Shell elongate, gradually tapering to the somewhat obtusely pointed apex. Transverse section subtriangular or plano-convex, the diameters about as two to one; length of shell about 3½ times as great as the width of the aperture; one side very slightly convex or nearly flat, the opposite side often regularly rounded, sometimes a little angular along the center. Aperture transverse, the margin on the flat side extended and forming a semicircular lip; that on the convex side transverse to the axis of the shell with sometimes a slight emargination near the middle.

Surface marked by fine lines of growth parallel to the margin of the aperture, and also on the flat side by numerous strong undulations following the lines of growth. The shell, where preserved, is apparently phosphoric, having the same texture and appearance as the *Lingulae*, with which it is associated; but it is more readily decomposed. It sometimes attains a length of one inch and a quarter.

Remarks.—This species is represented by a number of complete specimens, most of them small forms identical in shape and shell markings with the larger specimens. As the shell of one of the larger specimens is broken in half, a study of the ventral and dorsal sides of the same specimen can be made. The largest specimen measures 13 mm in length by 4 mm in width across the aperture.

Two opercula of *Hyolithes* in the collection have been tentatively referred to this species.

The shell preservation of *Hyolithes* is poorer than that of the brachiopods. This condition appears to be due to the extreme thinness of the shell and possibly to the original composition of the shell material. In the fossil horizon great numbers of specimens are unidentifiable because the shell is gone and only the characteristic shape retained by a mass of iron-stained clay remains.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.25, 76.29, 82.13, 82.18, 82.19, 82.21, 82.22.

Repository.—Figured specimen, U.S.N.M. 98708, locality 76.21.

Phylum ARTHROPODA
Class TRILOBITA
Order AGNOSTA
Family AGNOSTIDAE
"AGNOSTUS" NORDICUS Lochman, n. sp.
Plate 2, figures 20–22

Cephalon not known.

Pygidium small, strongly convex, 3 mm long by 3.75 mm wide; axial lobe very wide, convex, with a small anterior central node; dorsal furrows narrow, extremely shallow, present only a short distance from the anterior edge of pygidium; pleural lobes narrow, convex, tapering posteriorly, and dropping abruptly to the moderately wide, shallow marginal furrow; marginal border

slightly convex, narrow, with a small blunt spine on each side opposite posterior edge of axial lobe.

Surface of test smooth.

Remarks.—This species is assignable to a genus described in manuscript by Howell and Resser. It is represented in the collection by four well-preserved pygidia, of which the specific characters are quite distinct from those of the few known species of the genus in the U. S. National Museum collection.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.25, 76.34, 82.18.

Repository.—Holotype, pygidium, U.S.-N.M. 98695, locality 76.25.

Genus KORMAGNOSTUS Resser, 1938

Kormagnostus RESSER, *1938*, Geol. Soc. America, Spec. Paper 15, p. 49.

Emended description:

Cephalon regularly convex, widest along the median line; glabella convex, conical, consisting of a large posterior lobe and a small, low, subcircular anterior lobe; occipital lobes small, triangular in shape; dorsal furrow wide, deep along sides of posterior lobe, joining the deep transverse furrow across front of lobe; dorsal furrow narrow, shallow, faint to obsolete around anterior lobe. Sides of cephalon strongly convex, same width as posterior lobe of glabella; marginal furrow deep, well-defined; marginal border moderately wide, convex.

Pygidium strongly convex; axial lobe wider than pleural lobes, expanding slightly in posterior half, extending to marginal furrow; anterior portion of axial lobe with a small central node and marked by traces of two shallow furrows; dorsal furrows narrow, well-defined, parallel along anterior part of lobe, slightly arcuate along posterior part; pleural lobes narrow, roughly subtriangular in shape, tapering posteriorly; marginal furrow broad and shallow; marginal border moderately wide and convex with two short, blunt spines even with posterior edge of axial lobe.

Remarks.—The original description of the genus is in error in stating that the cephalon is "characterized by the absence of an anterior glabellar lobe" (Resser, op. cit. p. 49). An examination of the cotypes, U.S.N.M. 94842, of *Kormagnostus simplex* Resser, the genotype, reveals that the anterior lobe of the glabella is not absent but merely poorly defined because of its small size and slight convexity and because of the nearly obsolete condition of the anterior portion of the dorsal furrow. This feature can be seen on the figured cranidium (Resser, op. cit., pl. 9, fig. 11) of *K. simplex* Resser and also on the figured cranidium of *K. harlanensis* Resser (Resser, op. cit., pl. 10, fig. 11).

Kormagnostus is a clear-cut, distinctive genus common in the early Upper Cambrian and possibly restricted to the *Cedaria* zone. Five species, *Kormagnostus simplex* Resser, *K. harlanensis* Resser, *K. esterius* Lochman, *K. senatus* Lochman, and *K. splendens* Lochman are recognized in it. *Kormagnostus speciosus* Resser cannot be recognized as valid because the holotype, U.S.N.M. 94862, belongs to the genus *Proagnostus*.

KORMAGNOSTUS ESTERIUS
Lochman, n. sp.
Plate 2, figures 32–35

Cephalon small, convex, 4 mm long by 3.5 mm wide, decreasing in width near occipital border; glabella narrow, conical, two-thirds length of cephalon, consisting of a large posterior lobe with a small central node, and a small nearly circular anterior lobe; posterior lobe strongly convex, but convexity decreasing markedly to the flat anterior lobe; two pairs of short glabellar furrows on posterior lobe; occipital lobes small, triangular, slightly convex; dorsal furrow wide, deeply impressed along sides of posterior lobe, joining with deep transverse furrow across front of lobe, but absent on outer surface around the anterior lobe. Cheeks same width as posterior lobe of glabella, strongly convex at sides, dropping abruptly down to deep, moderately wide marginal furrow; marginal border of medium width, convex.

Pygidium small, strongly convex, measuring 3.5 mm in length by 4.5 mm in width; axial lobe strongly convex, wide, extending to marginal furrow, with a small central node, below which lies a narrow, shallow, V-shaped furrow; marked by traces of two pairs of short shallow furrows; dorsal fur-

rows narrow, well-defined, running parallel to a place opposite the axial node, then diverging outward to give posterior portion of axial lobe a bulbous appearance; pleural lobes narrow, convex, roughly subtriangular, tapering posteriorly; marginal furrow broad and shallow; marginal border of medium width, convex, with a short blunt spine at each side on line even with posterior edge of axial lobe.

Surface of test minutely granulated.

Remarks.—This species is represented in the collection by 24 specimens, including two associated cranidia and pygidia. The form is closely related to the abundant *Kormagnostus splendens* but is clearly distinguishable by the proportionately wider axial lobe and the divergence of the lateral furrows giving a more bulbous appearance to the pygidium, and by the poor development of the anterior lobe of the glabella. In these features it is very close to the genotype, *K. simplex* Resser.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.22, 76.24, 76.25, 76.23, 76.37, 82.13, 82.19, 82.22.

Repository.—Holotype, pygidium, U.S.-N.M. 98697, locality 82.19; paratype, cephalon, U.S.N.M. 98698, locality 76.25; unfigured paratype, pygidium, U.S.N.M. 98698, locality 76.25; unfigured paratypes, cranidia, U.S.N.M. 98699, locality 82.22 and U.S.N.M. 98697, locality 82.19.

KORMAGNOSTUS SENATUS
Lochman, n. sp.
Plate 2, figures 36, 37

Cephalon not known.

Pygidium small, strongly convex, 3 mm wide by 3 mm long; axial lobe wide, convex, with a small central node; four prominent shallow pits on the corners of a square enclosing the node, from the posterior pair of pits two shallow narrow furrows extending out to dorsal furrow; dorsal furrow shallow and narrow, parallel along anterior portion of axial lobe, then diverging slightly beyond the transverse furrows, but not extending completely around the posterior part of lobe; pleural lobes narrow, convex, tapering posteriorly; marginal furrow of medium width, shallow; marginal border convex, of medium width, narrowing anteriorly, with a short blunt spine on each side opposite posterior edge of axial lobe.

Outer surface of test smooth.

Remarks.—This species is represented in the collection by one well-preserved pygidium, from which only the right side of the marginal border and the minute axial node is missing. It is somewhat similar in appearance to *K. splendens* Lochman, n. sp. except for the presence of the four pits on the axial lobe. Its extreme rarity suggests that these might represent a deformity or an injury, but the very regular and definite arrangement of the pits renders such a conclusion still uncertain.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at locality 76.25.

Repository.—Holotype, pygidium, U.S.-N.M. 98696.

KORMAGNOSTUS SPLENDENS
Lochman, n. sp.
Plate 2, figures 23–31

Cephalon small, convex, 3 mm long by 3.5 mm wide; glabella one-third width of cephalon, consisting of posterior lobe with a very low central node, and a small slightly convex, semicircular anterior lobe; posterior lobe strongly convex, but convexity decreasing rapidly anteriorly; two pairs of faint glabellar furrows on posterior lobe; occipital lobes small, triangular, slightly convex; dorsal furrow wide, deeply impressed along side, of posterior lobe, very shallow and faint around anterior lobe; transverse furrow between lobes narrow, well-defined. Cheeks same width as glabella, regularly convex, sloping abruptly down to the moderately wide marginal furrow; marginal border of medium width, convex, narrowing posteriorly.

Thoracic segments narrow, with axial and pleural parts same width; axis moderately convex; pleurae nearly flat.

Pygidium small, moderately convex, 3 mm long by 3.75 mm wide; axial lobe convex, extending to marginal furrow, with a small central node, below which lies a narrow shallow, V-shaped furrow; marked by traces of two pairs of short shallow furrows; dorsal furrows narrow, well-defined, straight

along anterior third, then curving slightly out and back in to tapered posterior extremity; pleural lobes one-half width of axial, tapering posteriorly, sloping sharply down to the broad shallow marginal furrow; marginal border of medium width, convex, with a short blunt spine at each side on line even with posterior edge of axial lobe.

Outer surface of test covered with minute irregular ridges producing a crinkled type of ornamentation.

Remarks.—Well preserved cephalons and pygidia of this species occur very abundantly in the collection. The number of specimens is so large that a nice gradation in size can be worked out. The largest specimens measure: cephalon, 5 mm wide by 5 mm long; pygidium, 5 mm wide by 5 mm long.

The immature specimens of the cephalon show a marked flattening of the anterior margin of the marginal border, which gives the cephalon a square outline in contrast to the perfectly circular one of the adult. Also the axial lobe of the immature pygidium tends to taper more posteriorly than in the adult.

One of the young specimens is an enrolled form with the thoracic segments perfectly preserved.

The species differs from the closely allied *K. esterius* in the shape of the axial lobe of the pygidium and in the delineation of the anterior lobe of the glabella by the dorsal furrow.

Occurrences.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.24, 76.25, 76.27, 76.29, 76.34, 76.35, 76.37, 76.38, 82.13, 82.14, 82.18, 82.19, 82.22, 82.26.

Repository.—Holotype, pygidium, U.S.N.M. 98700, locality 82.13; paratype, cephalon, U.S.N.M. 98700, locality 82.13; paratype, enrolled individual, U.S.N.M. 98701, locality 76.34; paratype, unfigured pygidium, U.S.N.M. 98702, locality 82.19.

Genus PSEUDAGNOSTUS Jaekel, 1909
PSEUDAGNOSTUS MESLERI (Resser)
Plate 2, figures 38–43

Oedorhachis mesleri RESSER, *1938*, Geol. Soc. America, Spec. Paper 15, p. 50, pl. 10, figures 13, 14.

Original description.

When this small species is compared with *O. typicalis* a question concerning its generic position is raised. The pygidium has a swollen rear lobe, but this may be accentuated by flaws of preservation, and the cranidium has a median furrow which apparently is absent in *O. typicalis*. All furrows are deep, giving both shields considerable relief.

Supplementary description.

Cephalon small, convex; 1.5 mm long by 2 mm wide; glabella one-third width of cephalon, consisting of strongly convex posterior lobe and a small subtriangular, nearly flat anterior lobe separated by a narrow, shallow transverse furrow; occipital lobes small, subtriangular, slightly convex; dorsal furrow wide, deeply impressed around glabella and continuing to the well-defined anteromedian furrow. Cheeks slightly wider than glabella, regularly convex, sloping abruptly down to the deep, moderately wide marginal furrow; marginal border of medium width, convex, narrowing posteriorly.

Thoracic segments narrow, with axial and pleural portions approximately same width; axis moderately convex; pleurae slightly convex.

Pygidium small, convex, 2.5 mm long by 2.75 mm wide; axial lobe wide, with expanding posterior extending to marginal furrow; marked by a short heavy median spine anterocentrally placed and a pair of short shallow furrows extending in toward tip of spine; dorsal furrows deep, well-defined and straight along anterior third of axial lobe, then becoming shallow and curving back and down to marginal furrow at two-thirds length of axial lobe; pleural lobes narrow, tapered posteriorly, sloping abruptly down to the broad, well-defined marginal furrow; marginal border of medium width, convex, with a very short spine on each side opposite the posterior edge of axial lobe.

Outer surface of test covered with innumerable minute ridges and granules.

Remarks.—This species is represented in the collection by three cranidia, one excellently preserved pygidium, and one complete enrolled specimen of a young individual, all closely resembling the syntypes, U.S.N.M. 94864, described by Resser from the Nolichucky limestone of Tennessee.

A single pygidium from the Cap Moun-

tain formation of Texas, which is very closely allied to this species, differing from it chiefly in the proportions between the axial lobe and the pleural lobes, was described by Shumard as *Agnostus coloradensis* some years ago.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 72.34, 76.36.

Repository.—Plesiotypes, pygidium, U.S.N.M. 98703; cranidium, U.S.N.M. 98703, enrolled individual, U.S.N.M. 98703, all from locality 76.20.

Order OPISTHOPARIA
Family CREPICEPHALIDAE
Genus TRICREPICEPHALUS
Kobayashi, 1935
TRICREPICEPHALUS DAVIDI
Lochman, n. sp.
Plate 3, figures 26–34

Cranidium with a moderately convex, conical glabella; faint traces of three pairs of glabellar furrows; occipital ring of medium width and regularly convex; occipital furrow broad and rounded, shallow near axis of cranidium but deepening and narrowing towards each end; dorsal furrow completely outlining glabella. Fixed cheeks a little less than half width of glabella; palpebral lobes large, occupying one-third the length of suture line; an ocular ridge extending across fixed cheeks nearly to dorsal furrow at front of glabella; fixed cheeks merging into the narrow frontal limb, which slopes downward from dorsal furrow directly to the transverse furrow; furrow broad, shallow, marked by three small round crowded pits; frontal border of medium width, slightly convex, diverging at an angle of about 45° from anterior side of transverse furrow. Posterolateral limbs narrow, of moderate length, and marked by a well-defined intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin at center of cranidium and running outward along frontal border in a smooth curve to the frontal limb, then directly backward to palpebral lobe, around which it curves; passing outward and backward in a curve along the posterolateral limb and cutting posterior margin well within genal angle.

Pygidium square in outline, with two medium-sized, slightly curved pleural spines; axial lobe convex, broad with nearly parallel sides; axial lobe three-fourths the length of pygidium and divided into three segments and broad terminal section by three broad, shallow furrows; pleural lobes curving gently downward from the dorsal furrow, and then dropping abruptly down to margin; pleural furrows three, the anterior one wide, long and curved, posterior two shallow, narrow and short; lateral spines originating in strong bases at posterior corners of pleural lobes, directed upward, slightly curved outward and then in, measuring about twice the length of body of pygidium; marginal border narrow, flat; posterior margin straight.

Outer surface of cranidium coarsely granulated; surface of pygidium finely granulated with rows of large granules across the segments of the axial lobe.

Remarks.—This species is represented in the collection by about 25 cranidia and many pygidia whose association with the cranidia is probable but not certainly proven. The cranidia are identical with those of Ulrich's unnamed species, "sp. 3." They are widely distributed, occurring at many localities of the fossil horizon. The individuals in the collection show slight variations in the angle of the frontal border, but the peculiar features of the frontal border and transverse furrow are constant.

This species is very close to and (the author believes) may subsequently be proven to be identical with *T. nuperus* Resser from the Nolichucky of Alabama. It possesses the same extremely narrow frontal limb, the three closely crowded pits, and short broad glabella. The more rounded frontal border and the deeper furrows of *T. nuperus* Resser, the only differences observed, appear to be attributable to the flattening and distortion that the Alabama specimens clearly have undergone. The pygidium assigned to this species by Resser clearly can not belong to it, as it is the pygidium of a *Meteoraspis*.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.24, 76.25, 76.29, 76.37, 82.19, 82.22, 82.23, 76.39.

Repository.—Holotype, cranidium, U.S.N.M. 98740, locality 76.25; paratypes,

cranidia, U.S.N.M. 98741, locality 76.24; paratype, pygidium, U.S.N.M. 98742, locality 76.21, paratype, unfigured pygidium, U.S.N.M. 98740, locality 76.25.

TRICREPICEPHALUS NATALIA
Lochman, n. sp.
Plate 3, figures 35, 36

Cranidium with a moderately convex, conical glabella; three pairs of glabellar furrows; occipital ring of moderate width, marked at its center by a small rounded node; occipital furrow broad, rounded, moderately deep and narrowing at each end; prominent dorsal furrow extending entirely around glabella. Fixed cheeks a little more than one-third width of glabella and moderately convex; palpebral lobes medium-sized; a narrow elevated ocular ridge extending across the cheeks to anterior portion of glabella; fixed cheeks merging anteriorly into the moderately wide frontal limb, which slopes downward to the transverse furrow; the furrow well-defined, concave, and marked by three rounded pits; the narrow, slightly convex frontal border turning up sharply from the frontal limb at an angle approximating 90°; anterior margin evenly rounded. Posterolateral limbs moderate in length, marked by a medium-sized intramarginal furrow. Free cheeks unknown.

Facial suture cutting anterior margin on a line with side of glabella and running outward along the frontal border in a smooth curve to the frontal limb, then directly backward to palpebral lobe, around which it curves; finally passing outward and backward in a curve along the posterolateral limb and cutting the posterior margin well within the genal angle.

Cranidium 15 mm long by 13.5 mm wide.

Outer surface of test covered with small, scattered granules.

Pygidium not known.

Remarks.—This species is represented by seven well-preserved and nearly complete cranidia. No pygidium has yet been found in association with the cranidium. The cranidia are identical with those of Ulrich's unnamed "sp. 4." The specific distinction, the marked upturning of the frontal border, is well founded and not caused by some accident of preservation, for it occurs in a number of specimens from several different localities.

Occurrence.—Upper Cambrian, Bonneterre (*Cedaria* zone), at localities 76.24, 76.25, 76.29, 82.18, 82.19, 82.22.

Repository.—Holotype, cranidium, U.S.N.M. 98743, locality 76.25.

TRICREPICEPHALUS PARACOMUS
Lochman, n. sp.
Plate 3, figures 37–40

Cranidium small, short; glabella broadly conical, strongly convex; three short glabellar furrows probably present; occipital ring and furrow unknown; dorsal furrow deeply impressed. Fixed cheeks narrow, one-fourth width of glabella, elevated; palpebral lobes crescentiform, narrow; narrow, faint ocular ridge; frontal limb narrow, sloping regularly down to broad shallow transverse furrow with three small shallow pits; frontal border narrow, upturned, regularly convex; anterior margin rounded. Posterolateral limbs not known. Free cheek not known.

Facial suture cutting anterior margin on line with dorsal furrow, curving out to transverse furrow and then running straight back to and around palpebral lobes; farther course unknown.

Pygidium nearly square in outline with two medium-sized pleural spines; axial lobe convex, broad, with sides tapering slightly to rounded posterior end; axial lobe three-fourths length of pygidium and divided into three segments and terminal portion by shallow transverse furrows; pleural lobes flat, then dropping abruptly down to margin; only one broad anterior pleural furrow; lateral spines originating in strong bases at posterior corners of pleural lobes, sharply upturned and straight near base, rest unknown; posterior margin slightly curved.

Surface of test covered with medium-sized widely scattered granules.

Remarks.—Three small cranidia and several pygidia are referred to this species. It is very close to *T. comus* (Walcott) but the cranidium differs from that species in the wider frontal limb and the lessened convexity of the glabella, while the pygidium, though essentially similar to that assigned to *T. comus* (Walcott), has much heavier pleural spines.

Occurrence.—Upper Cambrian, Bonne-

terre dolomite (*Cedaria* zone), at localities 76.20, 76.24.

Repository.—Holotype, cranidium, U.S.-N.M. 98744, locality 76.20; paratype, pygidium, U.S.N.M. 98744a, locality 76.20.

TRICREPICEPHALUS BLOUNTENSIS Resser
Plate 3, figures 41, 42

Tricrepicephalus blountensis RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 104, pl. 14, fig. 3.

Cranidium with a moderately convex, conical glabella tapering to a rounded anterior; three pairs of glabellar furrows; occipital ring of medium width, convex, with a small median node; occipital furrow broad and shallow near middle, deepening and narrowing toward sides; a well-defined dorsal furrow. Fixed cheeks narrow, less than one-third width of glabella; palpebral lobes medium-sized; frontal limb moderately wide, sloping downward to the broad, shallow transverse furrow marked by three circular pits; flat frontal border slightly wider than frontal limb; anterior margin rounded at sides, tending to straighten across the front. Posterolateral limbs of medium length, narrow, with a broad intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin on line with dorsal furrow, curving outward to transverse furrow and thence backward to and around palpebral lobe; passing outward and backward in a curve to cut posterior margin well within genal angle.

Pygidium not known.

Outer surface of test sparsely covered with large granules.

Remarks.—A few cranidia in the Bonneterre material are referable to this species of *Tricrepicephalus*, recently described from the Nolichucky of Alabama. The proportions of the cranidium and the very distinctive circular pits are identical with those of the holotype, but the specimens are only one-half as large. The holotype, when compared with the Bonneterre specimens, shows clearly the slight broadening and flattening of the glabella which is a very characteristic development of the cranidium as the age and size of the animal increases.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at locality 76.20; plesiotype, cranidium, U.S.N.M. 98739, locality 76.20.

TRICREPICEPHALUS WALCOTTI (Lochman)
Plate 3, figures 43, 44

Crepicephalus thoosa WALCOTT (part), *1916*, Smithsonian Misc. Coll., vol. 64, no. 3, pp. 214, 215, pl. 31, figs. 1a, 1a′.

Paracrepicephalus walcotti LOCHMAN, *1936*, Jour. Paleontology, vol. 10, p. 39, pl. 9, figs. 29–31.

Tricrepicephalus walcotti (Lochman) RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 102, pl. 11, fig. 54.

The cranidium of this species is characterized by a wide, pointed frontal border, illustrated in Walcott's figures 1a, and 1a′, as well as by the elongate conical glabella and more thickly set surface granules cited by Walcott. (Lochman, 1936.)

Remarks.—This species occurs in moderate abundance in the Bonneterre, but is much less common than *T. rex* and *T. davidi*. Its presence is indicative of the late age of the Bonneterre fauna, as the group of *Tricrepicephalus* species with the pointed frontal border reach their fullest development in the *Crepicephalus* zone.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.20, 76.21, 76.24, 76.29, 76.34, 76.37, 82.13, 82.19, 82.22, 82.23.

Repository.—Plesiotype, cranidium, U.S.-N.M. 98747, locality 76.24.

TRICREPICEPHALUS REX Lochman, n. sp.
Plate 3, figures 45–51

Cranidium large, with moderately convex, broadly conical glabella; three pairs of faint glabellar furrows; occipital ring of medium width, convex, with a small median node; occipital furrow broad and shallow; dorsal furrow well-defined, outlining glabella. Fixed cheeks one-third width of glabella, nearly flat; palpebral lobes of medium size, situated posterior to transverse median line of glabella; ocular ridge narrow, faint, extending diagonally to front of glabella; frontal limb very narrow, flat; transverse furrow narrow, shallow, marked by three narrow, deep transverse pits; frontal border of medium width and convexity; anterior margin smoothly rounded. Posterolateral limbs of medium width and length with a broad, well-defined intramarginal furrow. Free cheek large, ocular platform rectangular, strongly convex, with

medium-sized eye; marginal furrow broad, well-defined; marginal border of medium width, nearly flat, with pointed anterior projection, and a slender flat genal spine.

Facial suture cutting anterior margin in front of dorsal furrow, curving out to transverse furrow, then running straight back to and curving around palpebral lobe; thence curving outward and backward to cut posterior margin within genal angle.

Outer surface of cranidium sparsely covered with large granules; a row of smaller granules across bottom of each transverse pit.

Pygidium nearly square in outline; axial lobe broad, convex, with sides tapering toward rounded posterior end, extending more than three-fourths length of pygidium and divided into three segments and a wide terminal section by three transverse furrows, which become progressively shallower toward posterior; pleural lobes as wide as axial, practically flat near dorsal furrow and dropping downward abruptly along the margin; anterior pleural furrow wide and deep, but posterior two shallow and narrow; pygidial spines originating in strong bases in sides of pleural lobes; spines upturned directly outward from their bases, continuing at a constant width for about half their length, then gradually becoming wider and flatter, assuming a spatulate shape, with a bluntly pointed tip.

Outer surface of pygidium granulated; granules coarse and arranged in single rows along the segments; spines covered with short irregular concentric venations; inner surface of test finely punctate.

Remarks.—Several cranidia and eight large and one small pygidia are referred to this species. The cranidia represent a species that was once commonly assigned to *T. texanus* (Shumard), as it also reaches the large size once thought to be a characteristic of that species.

The author believes that in all probability *T. rex* Lochman, n. sp. is conspecific with *T. alabamensis* Resser from the Nolichucky of Cedar Bluff, Alabama, but she hesitates to throw *T. rex* Lochman positively into synonymy until the character of the pygidial spines of *T. alabamensis* Resser are known. Except for this unknown factor the two species appear to be identical.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.20, 76.21, 76.28, 76.29, 76.36, 82.23.

Repository.—Holotype, cranidium, U.S.N.M. 98745, locality 76.28; paratype, free cheek, U.S.N.M. 98746, locality 76.20; paratype, pygidium, U.S.N.M. 98746a, locality 76.20; paratype, unfigured pygidium, U.S.N.M. 98746b, locality 76.20.

TRICREPICEPHALUS, sp. undet.

Remarks.—A large number of specimens of larval forms, in both the protaspid and metaspid stages have been obtained. These are especially abundant and excellently preserved at several of the Bonneterre localities. Because of this abundance a complete series of developmental stages can be obtained. The proportions of the protaspis and the appearance of the metaspis leave no doubt as to the generic relations of these forms, but as yet no specific determination can be made, as they do not occur in direct association with any single species.

Occurrences.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone) at localities 76.21, 76.22, 76.25, 76.27, 76.29, 76.34, 76.36, 76.33, 76.37, 76.38, 82.13, 82.17, 83.18, 82.19, 82.20, 82.21, 82.22, 82.23, 82.24, 82.26.

Genus METEORASPIS Resser, 1935

METEORASPIS DELIA Lochman, n. sp.

Plate 3, figures 14–20

Cranidium oblong in shape, with a prominent conical, strongly convex glabella; three pairs of glabellar furrows; occipital ring strongly convex, with greatest width at median axis of cranidium; occipital furrow of moderate depth, narrowing at each end, and broad and shallow along median axis; a moderately deep dorsal furrow completely outlining glabella. Fixed cheeks narrow and strongly convex; palpebral lobes medium-sized, about one-third the length of cranidium on suture line; the narrow fixed cheeks merging with the very narrow frontal limb, which slopes straight downward in the same plane as front of glabella to the deep but narrow transverse furrow; furrow marked by two oval pits; frontal border short and strongly rounded. Posterolateral limbs short and narrow, with

a well-defined intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin abruptly and passing directly backward to palpebral lobe, around which it curves; then running diagonally outward and backward in a long curve to cut posterior margin well within genal angle.

Largest cranidium 14 mm long by 10 mm wide.

Pygidium nearly square in outline; axial lobe broad, convex, with sides tapering slightly to broadly rounded posterior end; extending about three-fourths length of pygidium and divided into three segments and a terminal section by shallow transverse furrows; pleural lobes curving gently downward from dorsal furrow, then dropping abruptly downward near margin; pleural furrow shallow, curving backward toward base of lateral spines; the spines originating at posterolateral corners of pleural lobes, continuous with narrow marginal border, slightly upturned; posterior margin of pygidium straight.

Outer surface of test roughened by small irregular granules; inner surface finely punctate.

Remarks.—The species is represented by several medium-sized cranidia and pygidia, but it does not assume a prominence in the Bonneterre comparable to its position in the upper *Cedaria* faunas of the Cordilleran region—in the Missouri area it is definitely one of the less common and important members of the fauna.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.26, 76.37, 82.13, 82.18, 82.21, 76.24, 76.29.

Repository.—Holotype, cranidium, U.S.N.M. 98736, locality 76.20; unfigured paratype, cranidium, U.S.N.M. 98736a, locality 76.20; paratype, pygidia, U.S.N.M. 98737; locality 76.29; U.S.N.M. 98738, locality 76.37.

Family PLETHOPELTIDAE Raymond, 1924
Subfamily KINGSTONINAE Kobayashi, 1935
Genus ANKOURA Resser, 1938

Original description:

Small trilobites. The cranidial features can only be inferred from fragments. According to these the cranidium, simple in design, is rather highly arched in both directions; it consists of a plain, smooth glabella which occupies about two-thirds the length of the head and is rounded in front parallel to the anterior margin. The fixigenes are also simple triangles.

The libragenes are long and narrow.

Pygidium triangular in shape, with the margins turned steeply downward to the extent of being slightly rolled under. Axis wide and long with four or more furrows in exfoliated specimens. A unique feature is the swayback longitudinal outline of the axis, which elevates the rear end. Pleural lobes well fused.

Supplementary description. Cranidium small, regularly convex; glabella broadly conical, rounded in front, low; no glabellar furrows; occipital and dorsal furrows obsolete on outer surface; shallow and narrow on inner surface; occipital ring elliptical, slightly convex. Fixed cheeks wide, continuing slope of glabella; palpebral lobes very small, anterior to transverse median line of glabella; frontal limb continuous with slope of glabella; transverse furrow narrow; frontal border horizontal, flat or convex; anterior margin rounded. Posterolateral limbs short and wide with a broad, shallow intramarginal furrow on inner surface.

Facial suture cutting anterior margin on line with dorsal furrow, curving evenly to and thence around palpebral lobes, then continuing a smooth curve outward and downward to cut posterior margin just within genal angle.

Pygidium triangular in outline; axial lobe wide and low, with nearly straight sides and squared posterior edge; smooth on outer surface, marked on inner by more than six segments divided by narrow shallow furrows; pleural lobes slightly narrower than axial, flat or slightly convex, smooth on exterior; marked on interior by five or six narrow segments; marginal border vertical, very narrow anteriorly, increasing in width to elevated posterior median line.

Outer surface of test smooth except for several narrow transverse ridges on frontal border of cranidium; inner surface finely punctate.

Remarks.—*Ankoura* is a common and very characteristic genus of the *Cedaria* zone from the Cordilleran to the Appalachian region. It is closely allied to *Kingstonia* but differs from that genus in two clear-cut, easily recognized features—the

horizontal position of the frontal border of the cranidium, and the marked elevation at the posterior median line of the pygidium.

The genotype, *Ankoura triangularis* Resser, is not the most characteristic species of the genus, as it is decidedly specialized in the possession of the short blunt occipital spine on the cranidium and the small nodal development on the elevated posterior median line of the pygidium.

ANKOURA TRIANGULARIS Resser
Plate 4, figures 21–26

Ankoura triangularis RESSER, *1938*, Geol. Soc. America, Spec. Paper 15, p. 58, pl. 9, figure 33.

Original description:

Hundreds of these peculiar tails occur in certain thin zones. However, only fragments of cranidia are to be seen. The anterior portion of one, in a horizontal position is shown in the figure.

Supplementary description. Cranidium regularly convex, small; glabella subquadrate, moderately convex, expanding slightly anteriorly to a broad, rounded front; no glabellar furrows; occipital furrow narrow, shallow; occipital ring convex, roughly subtriangular, projected medially into a short blunt spine; dorsal furrow on inner surface only, outlining glabella clearly along sides, very faintly across front; fixed cheeks nearly as wide as glabella, regularly convex; palpebral lobes small, crescentiform, situated on suture line anterior to median line of cranidium; frontal limb of medium width, merging with front of glabella; a narrow shallow transverse furrow; frontal border narrow, flat, horizontal; anterior margin

---

EXPLANATION OF PLATE 3

FIGS. *1–5—Brassicicephalus pulchellus* Lochman, n. sp. *3, 4, 5*, Holotype; dorsal, front and side views. ×3. *1, 2*, Holotype, dorsal and side views, ×6, with different lighting to bring out ocular ridges and true course of intramarginal furrow on posterolateral limbs, U.S.N.M. 98748, loc. 76.25. (p. 39)

6–9—Coosia magna Lochman, n. sp. *6, 7*, Holotype; dorsal and side views of a squeeze taken from the impression, U.S.N.M. 98728, ×1, loc. 76.22. *8, 9*, Paratype, dorsal and side views of broken pygidium, U.S.N.M. 98729, loc. 76.20. (p. 35)

10–13—Avonaspis missouriensis Lochman, n. sp. *10*, Paratype, broken cranidium showing weak development of glabellar furrows on the mold of interior of test, U.S.N.M. 98733a, ×6, loc. 76.20. *11–13*, Holotype, nearly complete cranidium; *11, 13*, dorsal and front views, ×5; *12*, side view, ×6, U.S.N.M. 98733, loc. 76.20. (p. 41)

14–20—Meteoraspis delia Lochman, n. sp. *14–16*, Holotype; dorsal, side and front views of cranidium, U.S.N.M. 98736, ×2, loc. 76.20. *17, 18*, Paratype; dorsal and side views of pygidium with base of a spine, U.S.N.M. 98737, ×1, loc. 76.29. *19, 20*, Paratype; dorsal and side views of larger pygidium, U.S.N.M. 98738, ×1, loc. 76.37. (p. 30)

21–25—Syspacheilus camurus Lochman, n. sp. *25*, Holotype, a small well-preserved cranidium, U.S.N.M. 98722, ×5, loc. 76.29. *23, 24*, Paratype, largest cranidium; dorsal and side views, U.S.N.M. 98722a, ×2, loc. 76.29. *21, 22*, Paratype; side and dorsal views of cranidium with posterolateral limbs, U.S.N.M. 98723, ×4, loc. 82.19. (p. 42)

26–34—Tricrepicephalus davidi Lochman, n. sp. *26–32*, Views of three cranidia to illustrate growth within the species and the gradual smoothing and flattening of the profile with age. *26, 27*, Paratype; dorsal and side views, U.S.N.M. 98741, ×1, loc. 76.24; *28, 29*, dorsal and side views, U.S.N.M. 98741a, ×1, loc. 76.24. *30–32*, Holotype; dorsal, side and front views of well-preserved small cranidium, U.S.N.M. 98740, ×1, loc. 76.25. *33, 34*, Paratype, associated pygidium; dorsal and side views, U.S.N.M. 98742, ×1, loc. 76.21. (p. 27)

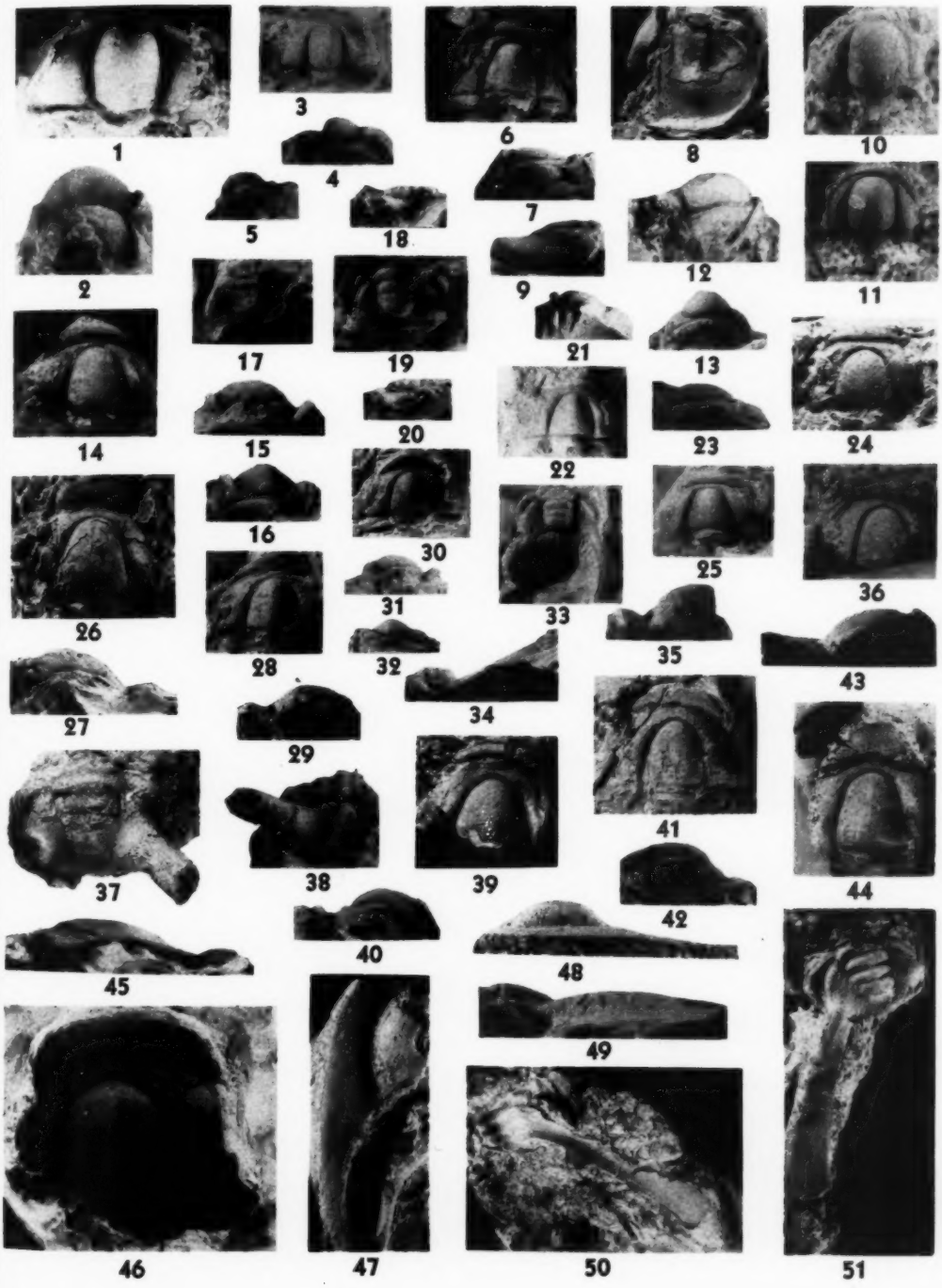
35, 36—Tricrepicephalus natalia Lochman, n. sp. Holotype; side and dorsal views, U.S.N.M. 98743, ×1, loc. 76.25. (p. 28)

37–40—Tricrepicephalus paracomus Lochman, n. sp. *39, 40*, Holotype; dorsal and side views of cranidium, U.S.N.M. 98744, ×2, loc. 76.20. *37, 38*, Paratype; dorsal and side views of pygidium, U.S.N.M. 98744a, ×2, loc. 76.20. (p. 28)

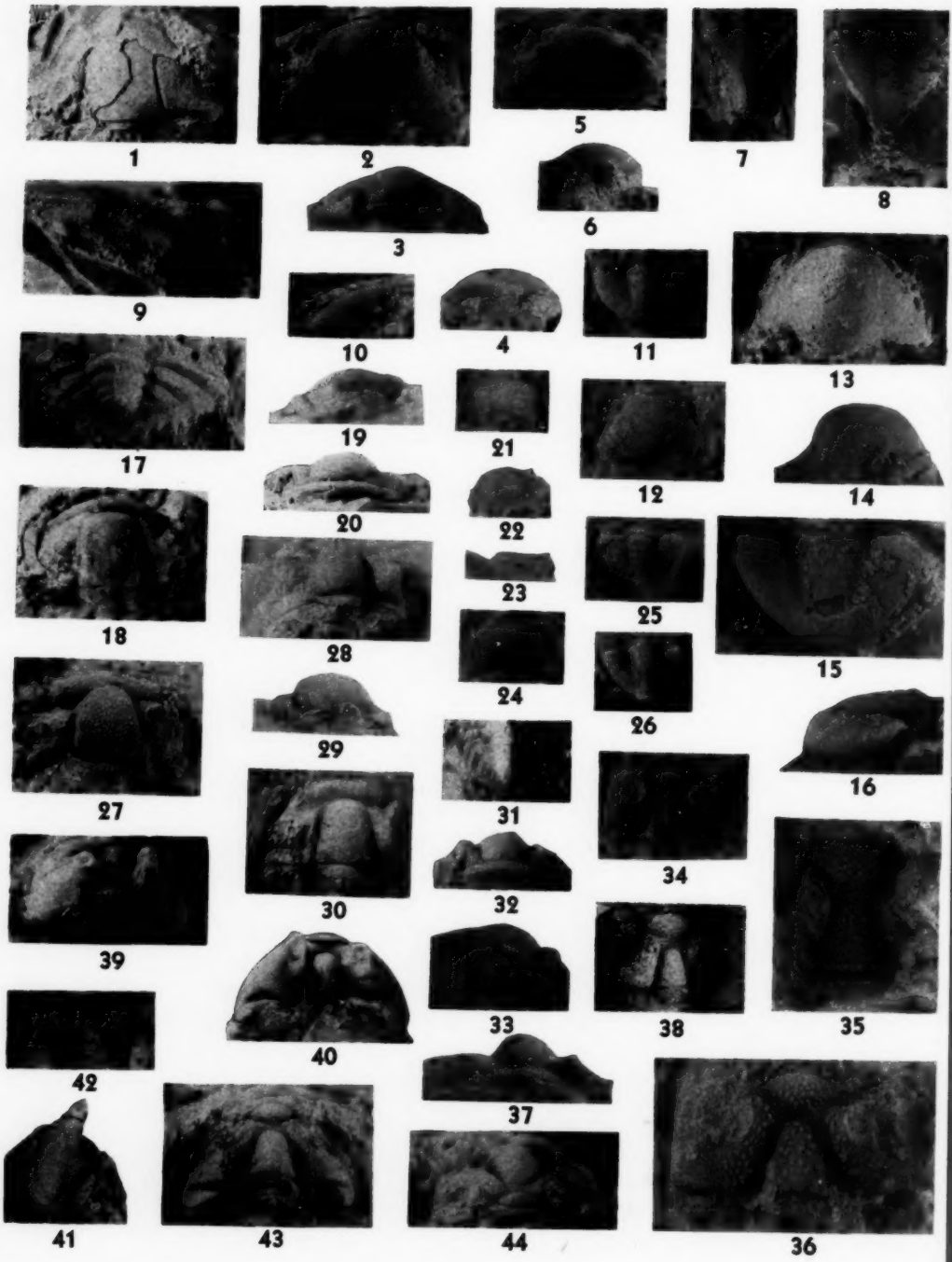
41, 42—Tricrepicephalus blountensis Resser. Plesiotype; dorsal and side views of a cranidium, U.S.N.M. 98739, ×1, loc. 76.20. (p. 29)

43, 44—Tricrepicephalus walcotti (Lochman). Plesiotype; side and dorsal views of a cranidium, U.S.N.M. 98747, ×1, loc. 76.24. (p. 29)

45–51—Tricrepicephalus rex Lochman, n. sp. *45, 46*, Holotype; side and dorsal views of a squeeze from an impression of a very large cranidium, U.S.N.M. 98745, ×1, loc. 76.28. *47, 48*, Paratype; dorsal and side views of a large free cheek, U.S.N.M. 98746, ×1, loc. 76.20. *49–51*, Paratype, a large well preserved pygidium, side view of specimen, dorsal view of impression, dorsal view of specimen, U.S.N.M. 98746a, ×1, loc. 76.20. (p. 29)



Lochman, Upper Cambrian Fossils



Lochman, Upper Cambrian Fossils

smoothly rounded. Posterolateral limbs wide, convex, with a narrow shallow intramarginal furrow.

Facial suture cutting frontal border abruptly and extending diagonally backward in a short straight line to palpebral lobe, around which it curves; then passing diagonally outward and backward to cut posterolateral margin at genal angle.

Pygidium triangular, nearly flat in profile with a slight upturn at posterior end; axial lobe one-third width of pygidium, evenly convex, sides nearly parallel, with posterior end merging directly into border; divided into six segments and a terminal node by narrow furrows on inner surface; dorsal furrow shallow, well-defined along anterior two-thirds of axial lobe; pleural lobes same width as axial, nearly flat, divided into three or four segments on inner surface; marginal border vertical, narrow anteriorly, increasing in width to posterior median line. Largest pygidium 3.5 mm long by 4.5 mm wide.

Outer surface of test smooth; anterior margin of frontal border of cranidium marked by several narrow transverse ridges; inner surface finely punctate.

Remarks.—The collections contain 12 fine specimens of the cranidium, one a young form, which is figured, and nearly 40 pygidia in all conditions of preservation. Again the preponderance of pygidia over cranidia, as noted by Resser in the Appalachian region, is an interesting feature. The species appears to be one of the less important members of the Bonneterre fauna.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.24, 76.25, 76.28, 76.29, 76.35, 76.37, 82.12, 82,13, 82.19, 82.22, 82.23.

Repository.—Plesiotype, cranidium, U.S.-

EXPLANATION OF PLATE 4

FIGS. *1–9—Kingstonia spicata* Lochman, n. sp. *2–4*, Holotype; dorsal, front and side views of a large well-preserved cranidium, U.S.N.M. 98758, ×2, loc. 76.24. *1*, Paratype, imperfect, partly peeled cranidium to show dorsal furrow on inner surface, U.S.N.M. 98759, ×2, loc. 82.19; *5, 6*, Paratype; dorsal and side views of a smaller cranidium, U.S.N.M. 98760, ×2, loc. 76.20; *7, 8*, Paratypes, a small and a large pygidium, U.S.N.M. 98759a, ×2, loc. 82.19. *9*, Paratype, a free cheek, U.S.N.M. 98759a, ×6, loc. 82.19. (p. 34)

10–12—Kingstonia apion Walcott. *10*, Plesiotype, a small free cheek, U.S.N.M. 98761, ×6, loc. 82.22. *11*, Plesiotype, a well-preserved pygidium, U.S.N.M. 98757, ×3, loc. 76.20. *12*, Plesiotype, a cranidium, U.S.N.M. 98756, ×3, loc. 82.19. (p. 34)

13–16—Kingstonia walcotti Resser. *13, 14*, Plesiotype; dorsal and side views of well-preserved cranidium, U.S.N.M. 98766, ×4, loc. 76.20. *15, 16*, Plesiotype, a pygidium, U.S.N.M 98766a, ×6, loc. 76.20. (p. 35)

17–20—Prochuangia? berryi Lochman, n. sp. *18–20*, Holotype; dorsal, side, and front views of most complete cranidium, U.S.N.M. 98750, ×3, loc. 76.29. *17*, Paratype, a small, fragmentary pygidium, U.S.N.M. 98752, ×6, loc. 76.21. (p. 39)

21–26—Ankoura triangularis Resser. *21*, Plesiotype, a small, young cranidium, U.S.N.M. 98754, ×3, loc. 76.20. *22, 24*, Plesiotype; side and dorsal views of an adult cranidium, U.S.N.M. 98753, ×3, loc. 82.23; *23, 25*, Plesiotype; side and dorsal views of a peeled pygidium showing furrows on inner surface, U.S.N.M. 98755. *26*, Plesiotype, pygidium with outer surface of test preserved, U.S.N.M. 98755a, ×3, loc. 82.19. (p. 32)

27–29—Genevievella tumida Lochman, n. sp. *27, 29*, Holotype; dorsal and side views of the most complete cranidium, U.S.N.M. 98749, *28*, Paratype, a fragmentary cranidium showing a posterolateral limb, U.S.N.M. 98749a, ×3, loc. 76.20. (p. 38)

30–33—Genevievella modesta Lochman, n. sp. *30, 32, 33*, Holotype; dorsal, front and side views of a small cranidium, U.S.N.M. 98764, ×5, loc. 76.20. *31*, Paratype, a small, well preserved pygidium, U.S.N.M. 98765, ×6, loc. 76.38. (p. 38)

34–38—Menomonia calymenoides (Whitfield). *35*, Plesiotype, large, fragmentary cranidium, U.S.N.M. 98785, ×5, loc. 72.29. *34, 36, 37*, Plesiotype, small well-preserved cranidium, dorsal view ×5, dorsal view ×10, front view ×10 to show amount of elevation of fixed cheeks and palpebral lobes, U.S.N.M. 98786, loc. 82.19. *38*, Holotype, dorsal view of the cranidium in the U. S. National Museum labeled as Whitfield's type, ×2, Dresbach formation, Eau Claire member, Eau Claire, Wisconsin. (p. 43)

39–42—Millardia avitas Walcott. *39–41*, Plesiotype; front, dorsal, and side views of a well preserved cephalon, U.S.N.M. 98790, ×4, loc. 76.20. *42*, Plesiotype, dorsal view of small cranidium with right free cheek in place, U.S.N.M. 98790a, ×6, loc. 76.20. (p. 44)

43, 44—Menomonia modesta Lochman, n. sp. Holotype; dorsal and front views of a small well-preserved cranidium, U.S.N.M. 98788, ×10, loc. 76.21. (p. 44)

N.M. 98753, locality 82.23; plesiotype, cranidium, U.S.N.M. 98754, locality 76.20, plesiotypes, pygidia, U.S.N.M. 98755 and U.S.N.M. 98755a, locality 82.19.

Genus KINGSTONIA Walcott, 1924
KINGSTONIA APION Walcott
Plate 4, figures 10–12

Kingstonia apion WALCOTT, *1924*, Smithsonian Misc. Coll., vol. 75, no. 2, p. 58; 1925, Smithsonian Misc. Coll., vol. 75, no. 3, p. 103, pl. 16, figs. 27–28a.

Kingstonia apion Walcott RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 82, pl. 12, figs. 1, 2.

Original description:

Cephalon semicircular in outline, without genal spines; nearly uniformly convex, all furrows weak or quite invisible externally, but the dorsal and occipital furrows more or less plainly indicated on inner surface of test; a very thin rim, usually striated, around middle half of head. Glabella subquadrate, rounded in front, not extending to the frontal groove, but leaving a wide invariably undefined brim between it and the rim. Fixed cheeks rather wide, eyes very small, situated nearly opposite but always behind the anterior extremity of the glabella. Suture extending almost directly forward from the eyes and cutting the rim abruptly. Behind the eyes it runs diagonally backward and outward, ending just within the genal angles. Free cheeks small, narrow.

Pygidium relatively large, externally unsegmented without border, varying in outline from subtriangular to transversely suboblong, with convex, steeply descending and often thick edge. Axis rather narrow, long, usually clearly, though never deeply, outlined on sides and behind. Where the shell is removed traces of segments usually observable on both the axis and pleural lobes.

Remarks.—A few cranidia and several pygidia are apparently specifically identical with the types of this species. The cranidium figured is slightly smaller than the type of Walcott, but no specific differences are apparent. The Bonneterre pygidium figured shows a faint longitudinal groove on each pleural lobe, but the significance of this marking is unknown. No other species of *Kingstonia* so marked is known, and the type pygidium of *Kingstonia apion* Walcott is too worn on the surface to have admitted its preservation if such a feature had existed.

The description quoted is that given for the genus, for Walcott says under the species "The generic description and figures present its more prominent characters."

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 82.19.

Repository.—Plesiotype, cranidium, U.S.N.M. 98756, locality 82.19; plesiotype, pygidium, U.S.N.M. 98757, locality 76.20; plesiotype, free cheek, U.S.N.M. 98761, locality 82.22.

KINGSTONIA SPICATA Lochman, n. sp.
Plate 4, figures 1–9

Cranidium moderately convex; glabella subquadrate, with moderately rounded front, slightly convex; no glabellar furrows; no occipital ring or furrow on outer surface, the glabella apparently terminating in an evenly rounded posterior margin, which is on a line with edge of posterolateral limbs; on inner surface a shallow occipital furrow and narrow occipital ring distinguishable; dorsal furrow absent on outer surface but deeply impressed on inner surface and completely outlining glabella. (In specimens in which outer surface is well preserved the reflected outline of the dorsal furrow can be seen, but outer surface itself is perfectly smooth.) Fixed cheeks of medium width, slightly convex; palpebral lobes small, crescentiform, close behind anterior end of glabella; frontal limb moderately wide, continuing slope of front of glabella; extremely narrow transverse furrow; a narrow vertical frontal border striated by several fine transverse ridges. Posterolateral limbs large and prominent, convex, marked by a shallow intramarginal furrow on inner surface. Free cheek very narrow and elongate, with a prominent vertical striated border along front and side; eye at inner angle; a short genal spine projecting straight outward from posterior margin.

Facial suture extending in a short straight line from anterior margin to palpebral lobe, around which it curves; passing diagonally outward and backward and cutting posterolateral margin just within genal angle.

Pygidium triangular, terminated posteriorly by a short thick spine; axial lobe of medium width, slightly convex, extending nearly to base of spine, with sides tapering posteriorly; on inner surface eight narrow segments separated by broad shallow furrows; dorsal furrow faint and shallow on outer surface, on inner surface clearly impressed along the sides and feebly around

the posterior end of axial lobe; pleural lobes as wide as axial lobe at its anterior edge, tapering posteriorly; lobes extending out flat from dorsal furrow for a short distance, then sloping down sharply to narrow marginal border, which broadens posteriorly into a short, thick spine; on inner surface four broad segments divided by shallow furrows along anterior part.

Outer surface of test smooth; inner surface finely punctate.

Remarks.—This species is very abundant in the Bonneterre material, well over 75 specimens having been obtained. They range in size from young individuals up to the largest adult forms, of which the cranidium measures 9 mm long by 14 mm wide, through the posterolateral limbs. The smaller cranidia are slightly more convex than the larger, which show a tendency to flatten but they never quite lose their convexity.

The specimens are found in all conditions of preservation, not a few of them being entire and with a well-preserved test. In the collection there are nine hand specimens from four different localities on which the cranidium and pygidium of one or more individuals are associated.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.23, 76.24, 76.25, 76.26 76.29, 82.12, 82.13, 82.15, 82.19, 82.22.

Repository.—Holotype, cranidium, U.S. N.M. 98758, locality 76.24; paratypes, cranidia, U.S.N.M. 98759, locality 82.19; U.S.N.M. 98760, locality 76.20; paratype, free cheek, U.S.N.M. 98759a, locality 82.19; paratypes, pygidia, U.S.N.M. 98759a, locality 82.19. Unfigured paratypes, growth stages of cranidium and pygidium: U.S.N.M. 98759b, locality 82.19; U.S.N.M. 98761a, locality 82.22; U.S.N.M. 98762, locality 82.13; U.S.N.M. 98763, locality 76.29.

KINGSTONIA WALCOTTI Resser
Plate 4, figures 13–16

Kingstonia walcotti RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 83, pl. 12, fig. 3, 4.

Original description:

This common species is characterized by its width and the bluntness of the triangular posterolateral limbs.

Supplementary description:

Cranidium strongly convex, with a medium-sized, subquadrate, convex glabella; no glabellar furrows; occipital ring and furrow obsolete on outer surface, glabella terminating in a bulging posterior margin; a shallow occipital furrow and very convex occipital ring demarcated on inner surface; wide shallow dorsal furrow on inner surface. Fixed cheeks of medium width, very convex; palpebral lobes small, just behind anterior end of glabella; frontal limb moderately wide, continuing downward slope of front of glabella; extremely narrow transverse furrow; narrow vertical frontal border marked by several fine transverse ridges. Posterolateral limbs short and wide, convex, with a shallow intramarginal furrow on inner surface. Free cheek not known.

Facial suture cutting anterior margin well out at sides, curving out to and around palpebral lobes; thence curving backward to cut posterior margin just within genal angle.

Pygidium small, with axial lobe one-third its width; axial lobe slightly convex, extending three-fourths its length, tapering to a broadly rounded posterior edge; exterior smooth, inner surface marked by five or six narrow segments; dorsal furrow shallow and faint; pleural lobes same width as axial, with four segments on inner surface; marginal border very narrow, vertical, increasing in width slightly to posterior median line.

Outer surface of test smooth; inner surface finely punctate.

Remarks.—This species is a small and rather common member of the Bonneterre fauna and is represented by many young as well as many adult individuals.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.24, 76.28, 82.12, 82.19, 82.22.

Repository.—Plesiotype, cranidium, U.S.-N.M. 98766, locality 76.20; plesiotype, pygidium. U.S.N.M. 98766a, locality 76.20; plesiotype, unfigured cranidium, U.S.N.M. 98766b, locality 76.20.

ANOMOCARIDAE Poulsen
Genus COOSIA Walcott, 1911
COOSIA MAGNA Lochman, n. sp.
Plate 3, figures 6–9

Cranidium elongate, with a moderately

convex, broadly conical glabella; no glabellar furrows; occipital ring of medium width, nearly flat; occipital furrow shallow, straight; dorsal furrow narrow and shallow, completely outlining glabella. Fixed cheeks medium-sized, one-third width of glabella, nearly flat; palpebral lobes medium-sized; a narrow ocular ridge extending across fixed cheeks to dorsal furrow; frontal limb narrow, flat; a shallow narrow transverse furrow; frontal border wide and convex; anterior margin evenly rounded. Posterolateral limbs broad and short, marked by a wide, shallow intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin near center of cranidium and running outward and backward in a continuous curve to palpebral lobe, around which it curves; thence passing straight outward and backward to cut posterior margin within genal angle.

Pygidium large, moderately convex, with a broad border; axial lobe of medium width and convexity, one-half length of pygidium, divided into three segments and terminal section by narrow, shallow furrows; pleural lobes slightly narrower than axial lobe, flat, divided into broad segments by three narrow furrows; dorsal furrow only along sides of axial lobe, which tapers posteriorly and merges outward and downward into the border; broad, nearly flat marginal border sharply defined by a sudden drop at edge of pleural lobes; a slight inward curvature of margin at posterior median line.

Outer surface of pygidium covered with minute granules; inner surface finely punctate; doublure marked with long irregular ridges paralleling margin.

Remarks.—This species is represented by three imperfect cranidia and a number of pygidia. The two are not directly associated in the Bonneterre material, but as they are proportional in size and are so associated on hand specimens from the Nolichucky limestone at Newmarket, Tennessee, where they occur, they are considered the same species.

It is quite possible that the outer surface of the cranidium is also granulated, as the rather imperfectly preserved surface of two cranidia appear to be slightly roughened. However, the preservation is too poor to permit certainty.

The cranidia are not unlike those assigned to *C. robusta* Walcott except for the greater width of the frontal border and fixed cheeks. The proportions of the pygidium also approximate those of *C. robusta* Walcott, but the axial lobe is shorter.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.22, 76.27, 76.37, 76.38.

Repository.—Holotype, cranidium, U.S.N.M. 98728, locality 76.22; paratype, pygidium, U.S.N.M. 98729, locality 76.20; paratype, unfigured cranidium, U.S.N.M. 98729, locality 76.20; paratype, unfigured pygidia, U.S.N.M. 98730, 98731, localities 76.27, 76.38.

Genus COOSELLA Lochman, 1936
COOSELLA PROLIFICA Lochman

Coosella prolifica LOCHMAN, *1936*, Jour. Paleontology, vol. 10, pp. 39, 40, pl. 9, figs. 4–11.

The description of this species, the genotype of *Coosella*, need not be repeated. A complete list of the localities at which it is found is here given.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone) at localities 76.20, 76.21, 76.22, 76.24, 76.25, 76.29, 76.34, 76.37, 76.38, 82.12, 82.13, 82.18, 82.19, 82.21, 82.22, 82.23, 82.24.

Family CEDARIIDAE Raymond
Genus CEDARINA Lochman, n. gen.

Cranidium narrow with low conical glabella; no trace of glabellar furrows; occipital and dorsal furrows shallow; occipital ring of medium width. Fixed cheeks narrow, low; palpebral lobes of medium width, on transverse median line of glabella; a faint diagonal ocular ridge; frontal limb sloping, frontal border horizontal, separated by a narrow, well-defined incurved transverse furrow. Posterolateral limbs narrow at eye, widening outward, of medium length, with a well-defined intramarginal furrow curving forward near margin. Free cheek narrow, with slender genal spine; low ocular platform; prominent eye at inner angle.

Pygidium transverse, narrow; axial lobe of medium width, tapered, extending nearly full length of pygidium, divided into four narrow segments and terminal portion; pleural lobes wide, flat, with three broad segments; a narrow marginal border.

Outer surface of test smooth; inner surface minutely punctate and roughened.

Genotype, *Cedarina vale* Lochman, n. gen., n. sp.

Remarks.—This genus is erected for a small species of the Bonneterre fauna which belongs with the Cedariidae but differs markedly from either *Cedaria* or *Acrohybus*. The peculiar facial suture and general structure of the carapace clearly ally it to these genera, but it differs in the preocular course of the facial suture, and the markedly transverse narrow shape of the pygidium. In these respects it shows decided affinities with *Cedaria tennesseensis* Walcott and *Cedaria burnetensis* (Walcott), so much so that the author believes that a careful restudy of the two latter species will lead to their removal from *Cedaria* (s.s.) as exemplified by *Cedaria prolifica* Walcott, the genotype, and their transfer to the genus *Cedarina*.

CEDARINA VALE Lochman, n. sp.
Plate 2, figures 50–53

Cranidium with a narrow conical glabella tapering slightly to a rounded front, moderately convex; no glabellar furrows; occipital ring of medium width, flat; occipital furrow broad and shallow; dorsal furrow very narrow, well-defined. Fixed cheeks narrow, one-third width of glabella, flat; palpebral lobes medium-sized, even with median line of glabella; a faint ocular ridge extending diagonally forward from palpebral lobe to front of glabella; frontal limb of medium width, sloping downward to a narrow transverse furrow, which describes an inward curve in front of glabella; frontal border same width as frontal limb, flat; anterior margin bluntly pointed. Posterolateral limbs of moderate length, narrow near eyes, increasing in width outward, marked by a narrow, deep intramarginal furrow, which turns and runs forward near lateral margin. Free cheek narrow, oblong, with pointed anterior projection and long pointed genal spine; eye situated at inner side; marginal furrow narrow, deep.

Facial suture cutting anterior margin near center of cranidium and passing backward in a smooth curve to transverse furrow, thence in a straight line directly to palpebral lobe, around which it curves; back of eye curving outward and forward for some distance before dropping backward to cut posterior margin a short distance within genal angle.

Pygidium transverse, short; axial lobe of medium width, convex, tapering posteriorly, divided into four narrow segments and terminal portion by narrow furrows; pleural lobes broad, very slightly convex, marked by three broad, posteriorly sloping furrows, which end at inner edge of narrow convex marginal border.

Outer surface of test smooth, with several transverse striations on margin of free cheek; inner surface of test punctate; frontal limb and free cheeks covered with a network of heavy venations.

Remarks.—The species is represented in the Bonneterre material by 22 cranidia, 12 pygidia and a number of free cheeks, all three parts associated on hand specimens from several localities. It is apparently a rather small and uncommon member of the Bonneterre fauna and is the latest known species of the *Cedaria* group.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.22, 76.29, 76.33, 76.34, 76.37, 82.25, 82,26.

Repository.—Holotype, cranidium, U.S.N.M. 98734, locality 76.21; paratype, pygidium U.S.N.M. 98735, locality 76.37; paratype, small pygidium damaged after picture taken, U.S.N.M. 98734a; locality 76.21; paratype, free cheek, U.S.N.M. 98735, locality 76.37.

LEIOSTEGIIDAE Bradley
Genus GENEVIEVELLA Lochman, 1936
GENEVIEVELLA NEUNIA Lochman

Genevievella neunia LOCHMAN, *1936*, Jour. Paleontology, vol. 10, p. 41, pl. 9, figs. 12–21.

This species, the genotype of *Genevievella*, was described in the cited publication. The genus has been found to be a very common and characteristic member of the faunas of the *Cedaria* zone throughout the Mississippi Valley and the Cordilleran regions.

A complete list of the Bonneterre localities at which this species is found is here given.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities

76.20, 76,21, 76,22, 76,24, 82.12, 82.18, 82.19, 82.22.

GENEVIEVELLA MODESTA
Lochman, n. sp.
Plate 4, figures 30–33

Cranidium square, with a slightly convex, subquadrate glabella; a posterior pair of arcuate glabellar furrows; occipital furrow narrow, shallow; occipital ring low, of medium width; dorsal furrow narrow, well-defined at sides, shallow across front of glabella. Fixed cheeks less than one-half width of glabella, nearly flat; palpebral lobes situated on transverse median line of glabella; ocular ridge well-defined, reaching glabella back of the anterior edge; transverse furrow shallow; frontal border narrow, nearly flat. Posterolateral limbs narrow, of medium length, with a broad, shallow intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin well out at sides, curving outward to transverse furrow, then back to and around palpebral lobes; thence running straight outward and slightly forward before curving abruptly backward to cut posterior margin within genal angle.

Pygidium small, broadly transverse; axial lobe of medium width, strongly convex, tapering posteriorly, reaching nearly to the posterior margin, and divided by narrow, shallow furrows into six segments and a terminal portion; dorsal furrow narrow, well-defined only along sides; pleural lobes narrower than axial, slightly convex, divided into five broad backward-curving segments, which continue out onto border nearly to margin; marginal border narrow, flat, crossed by raised pleural segments.

Outer surface of cranidium probably granulated; outer surface of pygidium ornamented by two rows of small granules along axial lobe, a pair to each segment, and a row of small granules on each pleural segment.

Remarks.—Several cranidia, all from a single locality, show a distinct change in the shape and convexity of the glabella when compared with the types of *Genevievella neunia* Lochman, though in all other respects the cranidia are identical. It is believed that this form represents a third, rather rare species of *Genevievella* in this fauna.

The small pygidium is tentatively referred to this species. It is not directly associated with the cranidium, but it does belong to the genus and shows several features that are different from the pygidium assigned to *G. neunia* Lochman. These are the greater number of segments and the two, instead of four rows of granules on the axial lobe. However, because of the scarcity of *Genevievella* pygidia in the collection and the small size of this pygidium, it is not certain whether these characters are of specific value or whether they might only be features of immaturity.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at locality 76.20, 76.38.

Repository.—Holotype, cranidium, U.S.N.M. 98764, locality 76.20; paratype, pygidium, U.S.N.M. 98765, locality 76.38.

GENEVIEVELLA TUMIDA
Lochman, n. sp.
Plate 4, figures 27–29

Cranidium broad, averaging 5.5 mm in length by 7 mm in width; glabella large, tumid, tapering anteriorly to a rounded front; anterior two pairs of glabellar furrows short and straight, posterior pair long and arcuate; occipital furrow broad and shallow; occipital ring of medium width, semicircular, flat; dorsal furrow broad, expanding opposite anterior part of glabella into two shallow depressions. Fixed cheeks half width of glabella, strongly convex; palpebral lobes not known, but apparently on transverse median line of glabella; narrow ocular ridge extending directly across fixed cheeks to dorsal furrow; transverse furrow shallow, continued laterally from dorsal furrow; frontal border of medium width, convex; anterior margin straight. Posterolateral limbs medium-sized, with narrow intramarginal furrow, which broadens and turns forward near lateral margin. Free cheek not known.

Facial suture cutting anterior margin on line with dorsal furrow, extending backward in a smooth curve to transverse furrow; then back in straight line to palpebral lobe; subsequent course not known.

Pygidium not known.

Outer surface of test thickly covered with large granules interspersed with smaller granules.

Remarks.—The two cranidia upon which this species is based occur at the same locality, and both are partially broken. However, they clearly represent a third species of *Genevievella* distinctive in the extreme tumidity of the glabella. No other parts of the carapace can at present be associated with the cranidia.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at locality 76.20.

Repository.—Holotype, cranidium, U.S.-N.M. 98749; paratype, cranidium, U.S.-N.M. 98749a.

Genus BRASSICICEPHALUS Lochman, n. gen.

Cranidium small, wide; glabella tumid, subquadrate, with parallel sides and broadly rounded front; no glabellar furrows; dorsal and occipital furrows narrow, well-defined; occipital ring strongly convex. Fixed cheeks wide; palpebral lobes small, on transverse median line of glabella; ocular ridge narrow, prominent, meeting dorsal furrow well behind front of glabella; frontal limb extremely narrow; transverse furrow almost obsolete on outer surface; frontal border narrow, abruptly downturned. Posterolateral limbs short and wide, with a narrow, well-defined intramarginal furrow widening and swinging forward near suture line.

Free cheek and pygidium not known.

Outer surface of test smooth; inner surface finely punctate.

Genotype, *Brassicicephalus pulchellus* Lochman, n. sp.

Remarks.—This genus is closely related to *Genevievella*, but differs markedly from it in the abrupt downturning of the frontal border, the obsolescence of the transverse furrow, the wider fixed cheeks, and the short, wide posterolateral limbs, all features that emphasize the smoothness, and squarish appearance of the cranidium. The genus is known at present to occur in the Bonneterre and also in the Abrigo limestone of Arizona, at both occurrences in the *Cedaria* zone.

BRASSICICEPHALUS PULCHELLUS Lochman, n. sp.
Plate 3, figures 1–5

Cranidium small, broad, averaging 3.5 mm in length by 4 mm in width; glabella tumid, subquadrate, with rounded front; no glabellar furrows; occipital furrow broad and shallow; occipital ring of medium width, convex; dorsal furrow narrow, clearly impressed around glabella. Fixed cheeks slightly over one-half width of glabella, convex; palpebral lobes narrow, small; a narrow ocular ridge extending nearly straight across fixed cheeks; frontal limb flat, extremely narrow; transverse furrow very narrow, obsolete on outer surface except at sides; frontal border narrow, at first continuing slope of frontal limb, then abruptly rolled downward into a vertical position; anterior margin slightly curved. Posterolateral limbs short, wide, with a narrow, deep intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin outside line of dorsal furrow, curving backward to transverse furrow, then extending straight back to and around palpebral lobes; then passing outward and backward diagonally, cutting posterior margin at genal angle.

Pygidium not known.

Outer surface of test smooth; inner surface finely punctate.

Remarks.—The species is known by more than 20 small cranidia from the Bonneterre material, but as yet no pygidia can be definitely associated with them. It is a distinctive but not especially common member of the fauna.

Occurrence.—Upper Cambrian, Bonneterre (*Cedaria* zone), at localities 76.21, 76.25, 76.37, 82.13.

Repository.—Holotype, cranidium, U.S.-N.M. 98748, locality 76.25; paratype, unfigured cranidium, U.S.N.M. 98748a, locality 76.25.

Genus PROCHUANGIA Kobayashi, 1935

PROCHUANGIA? BERRYI Lochman, n. sp.
Plate 4, figures 17–20

Cranidium wide, averaging 5 mm in length by 4 mm in width; glabella broad, subquadrate with parallel sides, moderately convex; a posterior pair of shallow arcuate glabellar furrows; occipital ring of medium

width, flat; occipital furrow narrow, well-defined; dorsal furrow narrow, clearly outlining glabella. Fixed cheeks not quite one-half width of glabella, slightly convex; palpebral lobes of medium size, situated even with median line of glabella; narrow faint ocular ridge; fixed cheeks sloping sharply downward to narrow transverse furrow; no frontal limb; a flat narrow frontal border, which rounds over into the ventral doublure; anterior margin rounded. Posterolateral limb narrow, with a narrow intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin on a line with eyes, making a short curve to transverse furrow and then running straight back to palpebral lobe, around which it curves; then passing straight outward; further course unknown.

Pygidium transverse in outline; axial lobe wide, strongly convex, tapering posteriorly, extending five-sixths length of pygidium, divided by broad shallow furrows into three segments and a terminal portion; pleural lobes same width as axial, convex, divided into three broad segments by broad, deep furrows; marginal border narrow, flat, edged by small spines, which are arranged in pairs opposite the end of each pleural segment, leaving the median posterior margin straight and smooth.

Outer surface of test very finely granulated; anterior part of frontal border and the doublure marked with narrow transverse ridges.

Remarks.—Eight cranidia and two pygidia, all fragmentary, have been referred to this species. All known portions of the cranidium and pygidium agree in every detail with the forms described as *Prochuangia* by Kobayashi in 1935. The discovery of more complete and better-preserved material may eventually demand the recognition of a new genus for this species, or else prove conclusively that it belongs to this genus, but at the present, because of the fragmentary nature of all the specimens, the generic identification remains open to question.

The species shows many similarities to *Genevievella*, but it cannot be placed in that genus, as in the cranidium the structure of the glabella and frontal border are quite different, and glabellar furrows are absent on the outer surface of the test, and the structure of the associated pygidium is entirely different from that of the pygidium of *Genevievella*.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.29, 76,38, 82.19.

Repository.—Holotype, cranidium, U.S.-N.M. 98750, locality 76.29; paratypes, unfigured cranidia: U.S.N.M. 98751, locality 76.29; U.S.N.M. 98752a, locality 76.21. Paratype, pygidium, U.S.N.M. 98752, locality 76.21; paratype, unfigured pygidium, U.S.N.M. 98752b, locality 76.21.

Family SOLENOPLEURIIDAE Angelin
Genus AVONASPIS Lochman, n. gen.

Cranidium small, strongly convex; glabella tumid, wide, with subparallel sides and broadly rounded front; two pairs of faint glabellar furrows on inner surface; dorsal and occipital furrows shallow, occipital ring triangular, with a median spine; fixed cheeks narrow; palpebral lobes small, situated anterior to transverse median line of glabella; a very faint ocular ridge; frontal limb and border narrow, separated by a shallow V-shaped transverse furrow. Posterolateral limbs short and wide, with a broad shallow intramarginal furrow.

Free cheek and pygidium not known.

Outer surface of test scattered with minute granules.

Genotype, *Avonaspis missouriensis* Lochman, n. sp.

Remarks.—The genus *Avonaspis* contains two species, *A. missouriensis* Lochman, and *A. anceps* (Resser). The genus is very closely related to *Welleraspis*, and when more complete material representative of the two genera has been obtained, it may be possible to unite them. At present, however, though both genera are known only from fragmentary specimens of cranidia and the pygidium of one species, the following apparent distinctions exist between them: *Avonaspis* differs from *Welleraspis* in the character of the frontal limb and border, the narrower fixed cheeks and the weak development of the glabellar furrows.

There is also a marked resemblance between *Avonaspis* and *Distazeris* Raymond, 1937; but, though practically identical in all other features, it differs decidedly from

Distazeris in the course of the facial suture anterior to the eyes and in the presence of a frontal border.

The cranidium described by Resser as *Stenochilina appalachia* Resser does not belong to that genus but to *Raaschella*.

AVONASPIS MISSOURIENSIS
Lochman, n. sp.
Plate 3, figures 10–13

Cranidium small and very rotund; glabella prominent, strongly convex; truncatoconical; two faint pairs of glabellar furrows on inner surface, posterior pair strongly arcuate, anterior slightly curved; occipital ring convex, triangular in shape, narrow at sides and increasing in width towards the center, projecting posteriorly into a short blunt spine; occipital furrow narrow and shallow; dorsal furrow narrow, well-defined. Fixed cheeks one-third width of glabella, slightly convex; palpebral lobes small, situated anterior to transverse median line of glabella; a faint straight ocular ridge; frontal limb extremely narrow, present only in front of fixed cheeks, tapering out anterior to glabella so that the narrow flat frontal border meets dorsal furrow at a V-shaped region where the narrow transverse furrow runs into the dorsal furrow; anterior margin smoothly rounded. Posterolateral limbs short, wide, with a shallow intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin on line with dorsal furrow, curving outward and then backward to and around the palpebral lobes; thence passing diagonally outward and backward, cutting posterior margin within genal angle.

Pygidium not known.

Outer surface of glabella smooth, rest of cranidium covered with fine granules; inner surface apparently smooth.

Remarks.—The species is represented by 10 cranidia in varying states of preservation, and none exceeding 3 mm in length, including the occipital spine. The average length is about 2–2½ mm. It differs from the Nolichucky species *A. anceps* (Resser) only in the very strong convexity of the glabella, which gives the entire cranidium a more tumid appearance than that of *A. anceps* (Resser), but a careful part-by-part comparison reveals that the frontal limb, frontal border, fixed cheeks and posterolateral limbs are apparently identical in both proportions and convexity.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 82.12.

Repository.—Holotype, cranidium, U.S.N.M. 98733, locality 76.20; paratype, cranidium, U.S.N.M. 98733a, locality 76.20.

Genus BLOUNTIA Walcott, 1916
BLOUNTIA, sp. undet. 1
Plate 2, figures 44–46

Cranidium not known.

Pygidium semioval; axial lobe of medium width, convex, over three-fourths length of pygidium, tapering to a narrow evenly rounded posterior termination; dorsal furrow shallow, well-defined along sides of lobe; outer surface practically smooth, but ten or more narrow segments on inner surface distinguishable through test; pleural lobes wide, regularly convex, with six or more narrow segments divided by narrow, shallow furrows, which continue for a short distance out onto border on inner surface of test; marginal border flat along sides but slightly concave around posterior portion of pygidium.

Outer surface of test minutely punctate.

Remarks.—This species is represented in the Bonneterre material by four complete pygidia and several fragments. It is apparently closely related to the pygidia assigned to *Maryvillia arion* Walcott but exhibits the following differences: 1) proportion of width to length is greater, 2) a prominent flat marginal border, and 3) the continuation of a few of the segments of the pleural lobes down on to the border.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76,22, 76,24.

Repository.—Figured pygidia, U.S.N.M. 98724, locality 76.20; U.S.N.M. 98725, locality 76.22.

BLOUNTIA, sp. undet. 2
Plate 2, figures 47, 48

A second species of *Blountia* is also represented in the collection only by pygidia. Seven specimens have been obtained, all of them apparently specifically identical with

the pygidia assigned to *Maryvillia arion* Walcott, but with all traces of segmentation nearly obliterated from the worn inner surface of the test. As no cranidia assignable to *Blountia* and associated with either of the two types of pygidia have been found in the Bonneterre material, it has been thought advisable to leave the forms unnamed though figured.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.24, 76.27, 82.13, 82.19.

Repository.—Figured pygidium, U.S.N.M. 98726, locality 82.13; unfigured pygidium, U.S.N.M. 98727, locality 76.27.

Genus SYSPACHEILUS
Resser, 1938

Cranidium with a short broadly conical glabella; no glabellar furrows; occipital and dorsal furrows narrow but well-defined; occipital ring convex. Fixed cheeks one-third width of glabella; palpebral lobes of medium size, on transverse median line of glabella; no ocular ridge; frontal limb and border sloping abruptly downward, separated by a broad, shallow transverse furrow. Posterolateral limbs narrow, of medium length, with a well-defined intramarginal furrow.

Free check not known.

Outer surface of test covered with small granules.

Genotype, *Syspacheilus typicalis* Resser.

Remarks.—The genus was erected for a single species in the *Cedaria* fauna of Georgia. It is represented in the Bonneterre material by a number of small cranidia. The form is quite provocative in that the rather generalized structure of the cranidium, is suggestive of several other genera of the *Cedaria* faunas though different from all. In the proportions of the parts to the whole, the cranidium is practically identical with that of *Coosella*, and it is undoubtedly closely related to this genus; but it differs in the absence of glabellar furrows and ocular ridges and in the downward slope of the frontal limb and border. This combination of differences is considered distinctive enough to merit generic recognition.

Syspacheilus CAMURUS
Lochman, n. sp.
Plate 3, figures 21–25

Cranidium with a short broadly conical glabella, bluntly rounded in front and moderately convex; no glabellar furrows; occipital ring of medium width, narrowing at sides, convex; occipital furrow narrow and deep; dorsal furrow of medium width, deeply impressed around glabella. Fixed cheeks one-third width of glabella, convex; palpebral lobes of medium size, situated centrally on suture line; palpebral furrows shallow, well-defined; no ocular ridge; frontal limb narrow, flat, steeply sloping; transverse furrow broad and shallow; frontal border twice as wide as frontal limb, strongly convex, with a prominent backward bulge on the median line of cranidium; anterior margin rounded on sides but nearly straight in front. Posterolateral limbs short and wide, marked by a broad, deep intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin on a line with dorsal furrow, running outward to transverse furrow and then straight backward to palpebral lobe, around which it curves; passing diagonally outward and backward to cut the posterior margin within genal angle.

Pygidium not known.

Outer surface of test thickly covered with minute granules; inner surface finely punctate.

Remarks.—This species is represented in the collection by 14 cranidia, quite well preserved but small. The largest specimen measures 7.5 mm in length by 6.5 mm in width. At present no pygidia are known that can be definitely associated with the species.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.29, 76.37, 76.38, 82.19.

Repository.—Holotype, cranidium, U.S.N.M. 98722, locality 76.29; paratype, largest cranidium, U.S.N.M. 98722a, locality 76.29; paratype, cranidium, U.S.N.M. 98723, locality 82.19; unfigured paratypes, cranidia, U.S.N.M. 98722, 98723, localities 76.29, 82.19.

Genus BONNETERRINA Lochman, 1936

BONNETERRINA PRIMA Lochman

Plate 2, figure 49

Bonneterrina prima LOCHMAN, *1936*, Jour. Paleontology, vol. 10, p. 42, pl. 9, fig. 1–3.

This species, the genotype of *Bonneterrina*, was described and discussed in the cited publication. In the present paper a small, nearly perfect cranidium, a paratype, is figured, and a list of the localities at which the species occurs is given.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.37, 82.13, 82.21, 82.23.

Repository.—Plesiotype, small crandium, U.S.N.M. 98732, locality 76.21.

Order PROPARIA

Family MENOMONIDAE

Genus MENOMONIA Walcott, 1916

MENOMONIA CALYMENOIDES (Whitfield)

Plate 4, figures 34–38

Conocephalites calymenoides WHITFIELD, *1878*, Geol. Survey Wisconsin, Ann. Rept. for 1877, p. 52; WHITFIELD, *1882*, Geol. of Wisconsin, vol. 4, p. 179; CHAMBERLIN, *1883*, Geol. of Wisconsin, vol. 1, p. 131; WHITFIELD, *1899*, New York Acad. Sci., Annals, vol. 12, p. 182.

Ptychoparia calymenoides (Whitfield) WALCOTT, *1884*, U. S. Geol. Survey, Mon. 8, p. 48; VODGES, *1893*, California Acad. Sci. Occ. Papers, vol. 4, p. 348.

Menomonia calymenoides (Whitfield) WALCOTT, *1916*, Smithsonian Misc. Coll., vol. 64, no. 3, pp. 162–163.

Original description:

Species less than medium size, the largest head noticed measuring scarcely three-eighths of an inch in length. The glabella and fixed cheeks, the only parts of the carapace positively identified, present much the general appearance of a species of *Calymene*. Glabella proportionally small, not exceeding half the entire length of the head, conical in form and obtusely pointed above, the width across the base rather more than equalling half the length, separated from the fixed cheeks by deep, abrupt dorsal furrows, surface convex, prominent, destitute of glabellar furrows; frontal limb nearly twice as wide between the suture lines as the greatest width of the glabella, its surface elevated into a highly convex, transversely oval boss or tubercle, which is separated from the glabella by a wide deep furrow; fixed cheeks highly and abruptly elevated, of proportionally large size; palpebral lobes semilunate or crescentiform, and situated opposite the upper end of the glabella; occipital furrow narrow, but deeply depressed; ring narrow, rounded and prominent. Facial suture nearly straight, in front of the eye lobes to the middle of the tuberosity of the frontal limb, around the front of which it seems to curve; behind the eye it is directed outward for nearly half the width of the lateral limb where it changes abruptly, forming an obtuse angle, and is then directed outward and backward with a slightly convex curvature of the posterior margin of the head at a point distant from the dorsal furrow about equal to the length of the glabella and occipital ring, forming large, triangular lateral limbs.

The tuberosity of the frontal limb, the large elevated fixed cheeks, deep dorsal furrows and small size are prominent features, and will serve to distinguish it from any known species.

Thorax long and narrow, the length exceeding one and a half times the greatest width; regularly and gradually narrowing from the occiput posteriorly, very highly arched transversely and strongly trilobed, consisting of 22 or more articulations. Axial lobe forming rather more than one-third of the entire width of the thorax, highly elevated, the curvature quite equalling a semicircle; lateral lobes narrower and deeper than the axial, the sides nearly vertical; dorsal furrows strongly marked; segments very short, the axial portion strongly rounded from front to back; pleura less strongly rounded than the axial portion, the anterior element forming nearly one-half the width at the inner end but decreasing outward, the furrow separating the two portions, deep and extending more than half the length of the pleura, outer portion flattened on the articular surface and rounded on the posterior margin; extremely rounded. Pygidium unknown.

Remarks.—This species is represented in the Bonneterre by a large number of well preserved cranidia that are similar to the type. Only the smaller cranidia are complete, as the larger lack one or both of the posterolateral limbs. No free cheek can be associated with the cranidia. On the Bonneterre specimens the outer surface is preserved and shows the fixed cheeks, glabella and frontal border to be covered with small granules and medium-sized granules with small central pits. The concave frontal limb is smooth. The cranidia range in size from 2.5 mm to 7 mm in length.

The Bonneterre cranidia indicate that a slight change in the ellipsoidal shape of the frontal border and the elevation of the eyes occurs with increase in size, as the larger specimens have the frontal border more elongate with the width nearly the same everywhere, and the eyes somewhat elevated.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities

76.21, 76.24, 76.25, 76.29, 82.813, 2.15, 82.18, 82.19, 82.21, 82.22, 82.23.

Repository.—Plesiotype, cranidia, U.S.N.M. 98785, locality 76.29; U.S.N.M. 98786, locality 82.19; plesiotype, unfigured cranidium, U.S.N.M. 98787, locality 76.25.

MENOMONIA MODESTA Lochman, n. sp.
Plate 4, figures 43, 44

Cranidium small, glabella subtriangular, slightly convex, about three-fourths length of cranidium; three pairs of glabellar furrows; occipital ring of medium width, regularly convex; occipital furrow narrow, deep; narrow, shallow dorsal furrow faintly outlining glabella. Fixed cheeks narrow, strongly convex; palpebral lobes small, crescentiform, located opposite anterior end of glabella; frontal limb of moderate width, slightly concave; frontal border wide, subtriangular; anterior margin rounded. Posterolateral limbs large, moderately long, with rounded genal angles and a deep, narrow intramarginal furrow. Free cheek not known.

Facial suture passing in a short arc from anterior margin to palpebral lobes, around which it curves; then running diagonally outward and backward to cut lateral margin anterior to genal angle.

Pygidium not known.

Outer surface of test covered with small granules; inner surface finely punctate.

Remarks.—More than 30 specimens, ranging in size from 0.75 mm to 5 mm in length, occur in the collection. They are well preserved, and many retain the posterolateral limbs. *M. modesta*, n. sp. differs from *M. calymenoides* (Whitfield) in the more pronounced triangular shape of the frontal border and in the slightly more anterior position of the eyes, which causes the frontal limb to be the narrowest part of the cranidium and gives the head an elongate, hourglass appearance in contrast to the broader proportions of the cranidium of *M. calymenoides* (Whitfield).

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.22, 76.24, 76.25, 76.29, 76.33, 76.36, 76.37, 82.19, 82.22.

Repository.—Holotype, cranidium, U.S.N.M. 98788, locality 76.21; paratype, unfigured cranidium, U.S.N.M. 98789, locality 76.26.

Genus MILLARDIA Walcott, 1916

Millardia appears to be a valid genus, not a synonym of *Menomonia*, as supposed by Resser (8). The characteristics of the two genera are tabulated on page 10.

MILLARDIA AVITAS Walcott
Plate 4, figures 39–42

Millardia avitas WALCOTT, *1926*, Smithsonian Misc. Coll., vol. 64, no. 3, p. 165, pl. 28, figs. 5–5e; LOCHMAN, *1938*, Jour. Paleontology, vol. 12, p. 84, pl. 18, figs. 4–5; LOCHMAN, *1938*, Jour. Paleontology, vol. 12, p. 469, pl. 56, figs. 27–28.

Menomonia avitas (Walcott) RESSER, *1938*, Smithsonian Misc. Coll., vol. 97, no. 10, p. 35.

Original description:

This species is represented by two very distinct cranidia. These differ in so many respects from the other species of the genus that detailed description and comparisons do not appear to be necessary. The most nearly related form is *M. optata* from the Upper Cambrian of Wisconsin. With a strong lens the surface is seen to be roughened by minute granules of varying size.

This species is of special interest, as it serves as a link between the Upper Cambrian fauna of the Appalachian trough in Pennsylvania and that of the Eau Claire subfauna of the Upper Cambrian of the upper Mississippian province.

Supplementary description:

Crandium transversely elongate, strongly convex, with rounded genal angles; glabella subtriangular, convex; three pairs of glabellar furrows; occipital ring of medium width, slightly convex; occipital furrow narrow, deep; dorsal furrow narrow, shallow, outlining glabella. Fixed cheeks narrow, vertical, forming eyestalks; palpebral lobes of medium width, crescentiform and situated at top of fixed cheeks opposite front of glabella; frontal limb short, flat, sloping down to the strongly convex frontal border; transverse furrow narrow, shallow. Posterolateral limbs narrow, elongate, marked by a narrow, deep intramarginal furrow, terminating in rounded genal angles. Free cheek large, elongate, convex, with small eye at inner angle; a well-defined marginal border only along anterior portion of cheek.

Facial suture cutting anterior margin directly in front of eye, passing straight

inward and upward to palpebral lobe, around which it curves; then passing in a long curve outward to near lateral margin where it cuves backward abruptly to cut lateral margin anterior to genal angle.

Pygidium not known.

Outer surface of test covered with fine granules, with larger granules scattered on frontal border, glabella, and occipital ring; anterior margin marked by several narrow transverse ridges.

Remarks.—This species is represented in the material by more than 40 well preserved and complete specimens of the cephalon, and many fragments of half the cephalon and free cheek. The ornamentation of the outer surface is well-preserved and identical with that of the type specimen.

The smaller cranidia show that unlike *Menomonia* the eyes are definitely stalked even in the immature forms.

One excellently preserved adult cranidium shows that the eye is situated around the outer side of the stalk, rather than directly on top.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.23, 76:25, 76.29, 76.34, 76.37, 76.38, 82.18, 82.19, 82.22, 82.23, 82.25.

Repository.—Plesiotype, cephalon, U.S.N.M. 98790, locality 76.20; plesiotype, cranidium, U.S.N.M. 987902, locality 76.20.

Family NORWOODIDAE
Genus NORWOODIA Walcott, 1916
NORWOODIA FILLIA Lochman, n. sp.
Plate 5, figures 17–21

Cranidium with a narrow, conical, slightly convex glabella; no glabellar furrows apparent; occipital ring of medium width, flat, with a small median ridge; occipital furrow broad, shallow; dorsal furrow shallow across front, deep at sides but ending before reaching intramarginal furrows. Fixed cheeks one-half width of glabella, flat; palpebral lobes of medium size, crescentiform, situated on transverse median line of glabella; frontal limb wide, convex; transverse furrow deep, narrow; frontal border of medium width, flat; anterior margin rounded. Posterolateral limbs of medium width, long, with a long, heavy genal spine; intramarginal furrow deep and narrow. Free cheek not known.

Facial suture cutting anterior margin well out at sides, curving out and then back to and around palpebral lobes; thence running outward and upward to cut lateral margin well in front of genal angle.

Pygidium not known.

Outer surface of test covered with fine granules, which are arranged in radiating rows on the frontal limb and portions of the posterolateral limbs.

Remarks.—Twenty specimens of the species occur in the collection. The cranidia differ from that of *N. gracilis* Walcott in the narrow transverse furrow and the apparent absence of an occipital spine. The species was identified by Ulrich as *N.* aff. *gracilis* in 1928.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.25, 76.34, 76.37, 82.12, 82.13, 82.15, 82.18, 82.19, 82.22.

Repository.—Holotype, cranidium, U.S.N.M. 98775, locality 82.19; paratype, cranidium, U.S.N.M. 98774, locality 76.37; paratype, cranidium, U.S.N.M. 98927, locality 82.22.

NORWOODIA BONNETERRENSIS
Lochman, n. sp.
Plate 5, figures 24–27

Cranidium narrow, elongate, with a conical, slightly convex glabella; no glabellar furrows apparent; occipital furrow shallow; occipital ring of medium width, flat; a long slender occipital spine probably present; dorsal furrow narrow, shallow across front of glabella, deepening along the sides but shallowing again before reaching intramarginal furrow. Fixed cheeks one-half width of glabella, slightly convex; palpebral lobes of medium size, crescentiform, situated on transverse median line of glabella; frontal limb wide, convex; transverse furrow broad and deep; frontal border of medium width, slightly convex and upturned; anterior margin rounded. Posterolateral limbs not known, but apparently bearing a long, slender curved genal spine.

Facial suture cutting anterior margin well out at sides, curving outward, then running straight back to and around palpebral lobes; further course not known.

Pygidium small, transverse; axial lobe nearly one-third its width, convex, tapering rapidly posteriorly and running about two-thirds the length of pygidium, divided into three narrow segments and a terminal portion; pleural lobes same width as axial, slightly convex, divided into four segments, with the anterior two pairs marked by narrow pleural furrows; marginal border narrow, well-defined.

Remarks.—In the Bonneterre material seven cranidia, two pygidia, and some long, slender curved genal spines have been referred to this species. The species is most interesting in that it appears to stand halfway between *N. gracilis* Walcott, the genotype, and *N. quadrata* (Whitfield) in its specific characters. It differs from *N. gracilis* Walcott in a somewhat greater convexity of the profile of the cranidium, a slightly narrower transverse furrow, and the broader aspect of the frontal border at the sides. These are features that the author believes may be attributable to the different facies in which the types of each species are preserved, but until specimens of *N. gracilis* Walcott can be found in limestone, these suspicions cannot be verified. On the other hand, as compared to *N. quadrata* (Whitfield), *N. bonneterrensis* exhibits a flatter profile of the cranidium and a deeper transverse furrow.

Occurrence. Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.21, 76.24, 76.29, 82.12, 82.13, 82.22.

Repository.—Holotype, cranidium, U.S.N.M. 98776, locality 76.21; paratype, genal spine, U.S.N.M. 98777, locality 82.22; paratype, pygidium, U.S.N.M. 98778, locality 76.29.

NORWOODIA QUADRATA
(Whitfield)
Plate 5, figures 22, 23

Conocephalites? quadratus WHITFIELD, *1880*, Wisconsin Geol. Survey, Ann. Rpt. for 1879, p. 47; *1882*, Geology Wisconsin, Survey of 1873–1879, vol. 4, p. 180, pl. 1, figs. 15–16; *1899*, New York Acad. Sci., Annals, vol. 12, p. 182.

Ptychoparia quadrangularis (Whitfield) VODGES, *1893*, California Acad. Sci., Occ. Papers, vol. 4, p. 353.

Ptychoparia? quadrata (Whitfield) MILLER, *1889*, N. Am. Geology and Paleontology, p. 565.

Norwoodia quadrata (Whitfield) RAASCH, *1935*, in Twenhofel, Raasch and Thwaites, Geol. Soc. America Bull., vol. 46, p. 1695 (cited in faunal list); RESSER, *1938*, Smithsonian Misc. Coll., vol. 97, no. 10, p. 36; RAASCH, *1938*, Geol. Soc. America, Sp. Paper 19, p. 89 (cited in faunal list).

Whitfieldina quadrata (Whitfield) RESSER, *1937*, Smithsonian Misc. Coll., vol. 95, no. 22, p. 27.

Original description:

Entire form of body unknown, the species being founded upon detached portions of the head only.

Glabella and fixed cheeks when united, minute, quadrangular in outline, the glabella forming but a small portion of the whole. The form of this latter part is quadrangular or very slightly tapering upward, and squarely truncate at the summit, the length being about once and a half as great as the greatest width, which is across the base. The surface is highly convex and destitute of glabella furrows, its margin abruptly limited by very deep and narrow dorsal furrows, which are continued in equal depth in front. Fixed cheeks, large and gently convex, their width being nearly once and a half that of the glabella, and their surface even with that of the posterior half of the frontal limb immediately in front of the glabella, marked on their margins by semicircular ocular sinuses of medium size. Anterior half of the frontal limb depressed, with the outer margin recurving, forming a broad, concave channel on the anterior half of this portion of the plate. Occipital ring very narrow, prominent and rounded, the groove narrow and deep, being a continuation of, and of similar character with the dorsal furrows bounding the glabella. The occipital furrow is entirely obsolete on the glabella, the posterior portion of this member being continued backward in a long curved spine, having a length equal to that of the glabella itself.

Movable cheeks short, but much extended laterally, the entire lateral length of each being nearly twice as great at the longitudinal diameter of the cheek along the line of the facial suture. Form of the cheek short-falcate, the posterior angle being curved slightly backward from a point opposite the eye lobe; anterior margin curved, with a constantly increasing curvature, from the anterior angle to the posterior projection. Surface of the cheek gently convex, the outer border much thickened on the under side, leaving a wide, deep groove on the cast, as seen in the rock.

Remarks.—Although this species does not occur in the Bonneterre collection, a critical review of its exact status among the Norwoodidae became imperative when the revision of the genera was undertaken. Although all the specimens assignable to this species that the author had ever seen from the *Cedaria* zone of Wisconsin definitely belonged to *Norwoodia*, nevertheless, Whit-

field's description and original drawing represented a species of *Norwoodina* close to *N. tunda* Lochman, n. sp. In order to settle the matter finally, the University of California very kindly loaned the author Whitfield's type, no. 1221, and gave her permission to photograph it, as it has never been so illustrated. It can be seen that the type, like other specimens from the Wisconsin material, is a true species of *Norwoodia*, closely related to *N. bonneterrensis* Lochman, n. sp., and that Whitfield's description and drawing erred seriously in ascribing wide fixed cheeks and a quadrate glabella to the form.

Genus NORWOODELLA Resser, 1938
NORWOODELLA HALLI Resser
Plate 5, figures 31–36

Norwoodella halli RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 90, pl. 10, figs. 45, 46.

Original description:

This species is similar to *N. walcotti*, differing in the better definition of the glabella and the longer brim.

Supplementary description:

Cranidium with a narrow, tapered, slightly convex, conical glabella; glabellar furrows very weak on inner surface; occipital ring subtriangular, of medium width, with a short, thick occipital spine; occipital furrow narrow, shallow; shallow, narrow dorsal furrow only on inner surface. Fixed cheeks extremely narrow and flat; palpebral lobes of medium size, crescentiform, lying just anterior to transverse median line of glabella; frontal limb of medium width, slightly convex; frontal border narrow, convex, scarcely distinguishable from frontal limb, both continuing forward in same plane as front of glabella; anterior margin bluntly pointed. Posterolateral limbs of medium width, long, with short, heavy genal spines; marked by a shallow, narrow intramarginal furrow. Free cheek subquadrate; a narrow, poorly defined marginal border with a pointed anterior projection and a short, blunt posterior spine; a distinctive slight inbending of lateral margin near the front.

Facial suture cutting anterior margin at center, curving outward and then backward to and around palpebral lobes; thence running directly outward almost to lateral margin before curving abruptly back to cut lateral margin in front of genal angle.

Pygidium narrow, transverse; axial lobe of medium width, tapered, extending three-fourths length of pygidium, divided into three faint segments and terminal portion; pleural lobes slightly wider than axial, moderately convex, with three faint segments; marginal border narrow, convex.

Outer surface of test smooth or very minutely granulated; inner surface finely punctate.

Remarks.—This is one of the most common species of the fauna and is represented by more than 200 specimens of cranidia and pygidia with many associations of these and the free cheeks. All sizes of cranidia ranging from 6 mm down to less than 1 mm in length are present and afford an excellent opportunity to study growth stages. It was found that the holaspid stages are quite constant in appearance and proportions, so that a cranidium of 1 mm could be recognized specifically. However, in the very smallest cranidia two differences were noted —a proportional shortening of the frontal limb and border, and an even rounding of the anterior margin. The shortening of the preglabellar area is consistent with such a change noted in the meraspid stage of all trilobites.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.22, 76.24, 76.25, 76.26, 76.29, 76.33, 76.37, 82.12, 82.13, 82.18, 82.19, 82.20, 82.21, 82.22, 82.23.

Repository.—Plesiotype, cranidia, U.S.-N.M. 98767, 98768, localities 76.27, 76.26; plesiotype, pygidium, U.S.N.M. 98767b, locality 76.25; plesiotype, free cheek, U.S.-N.M. 98767a, 98769, localities 76.25, 82.19.

NORWOODELLA SAFFORDI (Walcott)
Plate 5, figures 28–30

Norwoodia saffordi WALCOTT, *1916*, Smithsonian Misc. Coll., vol. 64, no. 3, p. 171, pl. 27, figs. 1–1f.

Norwoodella saffordi (Walcott) RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 89, pl. 10, figs. 40, 41, 49, 50.

Original description:

This species differs from *Norwoodia gracilis* in the form of the frontal limb and border, fixed cheeks, and genal spines, and in having eight instead of nine thoracic segments.

The outer surface of the test appears to have been rather strongly granulated.

Supplementary description:

Cranidium elongate with narrow conical glabella, slightly convex; no glabellar furrows; occipital ring subtriangular, of medium width, extended into short, thick occipital spine; occipital furrow narrow, shallow; dorsal furrow narrow, clearly defined on inner surface, but faint on outer. Fixed cheeks extremely narrow, slightly convex; palpebral lobes of medium size, crescentiform, lying slightly anterior to transverse median line of glabella; frontal limb of medium width, flat near glabella, then sloping steeply downward to narrow frontal border, which is distinguishable only by a slight change in slope; anterior margin rounded. Posterolateral limbs of medium width, long, with short, heavy genal spines. Free cheek subtriangular with anterior and outer posterior angles pointed; marginal furrow obsolete on outer surface.

Facial suture cutting anterior margin at the center, curving outward and then backward to and round palpebral lobes; thence running directly outward almost to lateral margin before curving abruptly back to cut lateral margin in front of genal angle.

Pygidium small, subtriangular; axial lobe one-third its width, convex, extending nearly its full length, divided into three narrow segments and a terminal portion; pleural lobes same width as axial, slightly convex, marked by three well-defined segments; marginal border extremely narrow.

Outer surface of test finely granulated; inner surface minutely punctate.

Remarks.—This species is represented in the material by 10 cranidia. It is much less common than the closely related *N. halli* Resser; and several cranidia have been observed that appear to be half-way between these two distinct species in the character of the frontal limb and border, suggesting the possibility of obtaining a complete gradational series between the two species if a larger number of specimens were obtained.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.24, 76.26, 76.34, 76.37, 82.13, 82.19, 82.22, 82.12.

Repository.—Plesiotype, cranidium, U.S.N.M. 98770, locality 76.37; unfigured cranidia, U.S.N.M. 98772, locality 76.26; U.S.N.M. 98773, locality 82.13; plesiotype, free cheek, U.S.N.M. 98771, locality 82.22.

Genus NORWOODINA Lochman, n. gen.

Cephalon short, transverse; cranidium short and broad, glabella subquadrate, convex, with front tapered and rounded; two to three pairs of short, straight glabellar furrows; dorsal and occipital furrows narrow, shallow; occipital ring nearly flat, with a short heavy spine. Fixed cheeks approximately same width as glabella, low; palpebral lobe small, anterior to transverse median line of glabella; ocular ridge prominent, narrow, straight; frontal limb wider than frontal border, separated by a narrow well-defined transverse furrow; anterior margin rounded. Posterolateral limbs moderately wide, variable in length, with a well-defined intramarginal furrow; genal spine variable in length and size. Free cheek small, short, triangular, with eye at inner angle; ocular platform low, slightly wider than marginal border; marginal furrow narrow, shallow. Facial suture cutting anterior margin well out at side, curving outward and then backward to and around palpebral lobe; thence running straight outward to near marginal furrow before curving backward to cut lateral margin anterior to genal spine.

Thorax of eight narrow segments; axial lobe same width as pleural lobes, moderately convex; pleural lobes nearly flat; segments with narrow, shallow pleural furrows and slightly falcate terminations.

Pygidium small, transverse; axial lobe narrow, moderately convex, with four to six segments and terminal portion; pleural lobes wider than axial, slightly convex, with four segments; marginal border very narrow.

Outer surface of test covered with small granules; inner surface minutely punctate.

Genotype, *Norwoodina tenera* (Walcott).

Remarks.—Among the species of Walcott's *Norwoodia*, three distinct groups can now be recognized, *Norwoodia* (s. s.), *Norwoodella*, and the genus *Norwoodina*, here described, exemplified by *N. tenera* (Walcott), the genotype. As the members of the Norwoodidae are quite abundant, both in species and in individuals in the Bonne-

terre, a detailed study of this group was made in connection with the Bonneterre work. The diagnostic characters of each genus are tabulated on pages 10 and 11.

Norwoodina tenera (Walcott) was chosen as the genotype because it was the first species to be described, is still the most adequately known one, and is structurally very close to the generalized pattern that is conceived as the basis for the genus. Within the genus specific variation trended toward a widening of the cephalon, which led to a widening of both the fixed and free cheeks, a broadening of the posterolateral limbs, and an increase in the size and length of the genal spines.

NORWOODINA APPALACHIA (Resser)
Plate 5, figures 1–7

Utia? appalachia RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 105, pl. 14, figure 12.

Original description:

Whether this species is related to *Utia* or merely resembles it by accident cannot now be determined, although the latter will probably prove to be the case. *U.* (?) *appalachia* has the eyes elevated by a strong bowing of the fixigenes.

Supplementary description:

Cranidium broad, 3 mm by 3 mm; small, subquadrate glabella, rounded in front, strongly convex, with a low median ridge; no glabellar furrows; occipital ring triangular, with a small node forming base of a long, slender occipital spine; occipital furrow very narrow and shallow; dorsal furrow narrow, deep around front and sides of glabella, ending before reaching intramarginal furrow. Fixed cheeks same width as glabella, flat; palpebral lobes small, anterior to transverse median line of glabella; a narrow, well-defined, straight ocular ridge; frontal border wide, vertical in position; a narrow, shallow transverse furrow marked on each side by four minute pits; narrow, slightly convex, horizontal frontal border; anterior margin rounded. Posterolateral limbs of medium width, long, with a heavy, slightly recurved genal spine; a narrow, deep intramarginal furrow, joining marginal furrow in a deep *L*-shaped depression. Free cheek not known.

Facial suture cutting anterior margin near sides, curving outward and then straight back to and around pelpebral lobes; thence passing straight outward before curving abruptly back to cut lateral margin in front of genal angle.

Pygidium small, strongly convex; axial lobe narrow, convex, tapered, extending almost full length of pygidium, divided into six narrow segments; pleural lobes wider than axial, regularly convex, divided into six narrow segments running nearly to margin; extremely narrow marginal border.

Outer surface minutely and thickly granulated; inner surface punctate.

Remarks.—The holotype of this species, U.S.N.M. 94977, is a fragmentary cranidium from the Nolichucky limestone, six miles south of Rome, Georgia. The posterolateral limbs are broken off, a very common accident as shown by the Bonneterre material. The frontal border is still present on the specimen, though not shown in Dr. Resser's picture, as it is covered by the matrix.

More than 40 specimens of the species occur in the Bonneterre material, an abundance which affords a more complete knowledge of the species. The vast majority consist only of the central portion of the cranidium, similar to the holotype, and specimens with both of the wide, heavy posterolateral limbs, as on pl. 5, figure 1, are very rare. The very narrow horizontal frontal border is also frequently broken off, either in the field or accidentally in the laboratory during the preparation of the material, as it is very thin and delicate, and its horizontal position is unsuspected by the preparator unless he has seen a complete specimen and takes special pains when working on this portion of the cranidium.

This species apparently represents the same form that was described by Walcott as *N. ponderosa*. The type material and the additional specimens recently cited by Resser (9, p. 91) are all poorly preserved in shale with the anterior outline of the cranidium so indistinct that it is uncertain whether or not the species has a frontal border. In all other respects the cranidia assigned to the two species are similar.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.22, 76.38, 82.18, 82.19, 82.20, 82.23, 82.24, 82.26.

Repository.—Plesiotypes, cranidia, U.S.N.M. 98783, 98783a, locality 76.20; plesiotype, cranidium, U.S.N.M. 98784, locality 76.21; plesiotype, pygidium, U.S.N.M. 98784a, locality 76.21.

NORWOODINA TUNDA Lochman, n. sp.
Plate 5, figures 8–11

Cranidium broad, with a narrow, strongly convex, parallel-sided glabella; no glabellar furrows; occipital ring small, moderately convex, with small median node forming the base of a short, slender occipital spine; occipital furrow narrow, very shallow; dorsal furrow narrow, shallow across front and deep at sides. Fixed cheeks broad, 1½ times width of glabella, moderately convex; palpebral lobes small, situated anterior to transverse median line of glabella; narrow, well-defined ocular ridge extending straight across cheeks; frontal limb convex, of medium width; narrow, shallow transverse furrow; flat narrow frontal border, anterior margin rounded. Posterolateral limbs narrow, transversely elongate, with a short, slender genal spine; a deep, broad intramarginal furrow. Free cheek not known.

Facial suture cutting anterior margin well out at sides, curving outward and then straight back to and around palpebral lobes; thence passing diagonally outward and backward to cut lateral margin anterior to genal angle.

Pygidium not known.

Outer surface of test minutely granulated, with a few larger granules on fixed cheeks; frontal border marked by several narrow, irregular transverse ridges.

Remarks.—This species, represented in the material by 14 specimens, is one of the less common forms of *Norwoodina*, but it is very significant as its cranidial structure is intermediate in position between that of *N. tenera* (Walcott), and the extreme species, *N. appalachia* (Resser).

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 82.13.

Repository.—Holotype, cranidium, U.S.N.M. 98782, locality 76.20; paratype, cranidium, U.S.N.M. 98926, locality 76.21.

NORWOODINA TENERA (Walcott)
Plate 5, figures 12–14

Norwoodia tenera WALCOTT, *1916*, Smithsonian Misc. Coll., vol. 64, no. 3, p. 172.
Norwoodia tenera Walcott LOCHMAN, *1938*, Jour. Paleontology, vol. 12, pl. 18, figs. 11–13.
Holcacephalus granulatus RESSER, *1938*, Geol. Soc. America, Sp. Paper 15, p. 81, pl. 9, figures 15–17.

Original description:

In general form the dorsal shield of this species resembles that of *N. simplex*, but in details it is quite distinct. It has eight thoracic segments, the pleural lobes of which have a very narrow pleural furrow and slightly falcate ends; a slender median spine occurs on the third, fifth and seventh segments of the axial lobe.

Surface minutely granular with a few large scattered granules on the cephalon, thoracic segments, and pygidium.

The largest entire specimen has a length of 3.5 mm. Cranidium, 1.5 mm. Thorax, 1.5 mm. Pygidium, 0.5 mm.

The largest cranidium in the collection has a length of 4 mm, which on the basis of the entire dorsal shield mentioned would give a total length of about 9.5 mm.

This small, neat species is abundant on two or three thin layers of shaly limestone of the Weeks formation.

Remarks.—More than 80 specimens of this species including three associations of cranidium and pygidium occur in the collection. The majority are well preserved and nearly complete, except for the posterolateral limbs. On several of the cranidia and one of the pygidia the minute granulations of the surface are excellently shown.

An examination of the abundant material from the Bonneterre and also from the Weeks formation indicates that slight variations in the convexity of the glabella and the profile of the cranidium can hardly be regarded as other than individual differences.

The Bonneterre specimens are all small. The cranidium averages about 2 mm in length and the pygidium 0.5 mm.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.22, 76.24, 76.25, 76.29, 76.33, 76.34, 76.38, 82.19, 82.20.

Repository.—Plesiotype, cranidia, U.S.N.M. 98779, locality 76.20; unfigured pygidia, U.S.N.M. 98780, locality 76.21.

NORWOODINA TENERA CUNEIFERA
Lochman, n. var.
Plate 5, figures 15, 16

Cranidium similar in all features to *N. tenera* (Walcott), but with a low V-shaped ridge extending across the frontal limb from dorsal furrow to frontal border interrupting the transverse furrow.

Free cheek and pygidium not known.

Several cranidia in the collection show this small distinctive variation from the type of cranidium normal for *N. tenera* (Walcott). As this is the first record of this variation, it may be a local variety. The species has not been studied thoroughly nor is it known at many localities.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at locality 76.20.

Repository.—Holotype, cranidium, U.S.-N.M. 98781, locality 76.20.

Family AVONINIDAE
Genus AVONINA Lochman, 1936
AVONINA BIZARRIA Lochman

Avonina bizarria LOCHMAN, *1936*, Jour. Paleontology, vol. 10, pp. 42, 43, pl. 9, figs. 22–26.

This species, the genotype of *Avonina*, was described and discussed in the cited publication.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities, 76.20, 82.19, 82.22.

Superorder CIRRIPEDIA?
Genus KINSABIA Lochman, n. gen.

Individual plates depressed conical, with elevated acentric apices; arranged in a graduated series increasing in size outward from a linear margin, which lies on the apical side of the plates; plates becoming progressively smaller towards this margin until they appear as overlapping, very rugose nodes, which merge into a sinuous marginal band covered only with small granules; the plates appearing to fit directly against each other or to overlap because of progressive growth, but not showing any evidence of a true imbricating structure.

Shell composed of a dark thick outer layer and a light thick central layer, each consisting of numerous lamellae; and a very thin innermost nacreous layer; each layer of uniform thickness over all parts of the shell.

Surface markings consisting of numerous strong wrinkles, concentric with apex and covered with minute pustules.

Interior surface of plates smooth, with a few ridges near the margin and some irregularly scattered granules.

Genotype.—*Kinsabia varigata* Lochman, n. sp.

KINSABIA VARIGATA Lochman, n. sp.
Plate 2, figures 10, 11

Individual plates depressed conical, with elevated acentric apices; a narrow short slope forward from the apex, and a long slope backward; margin flattened. Larger plates 3 mm long by 2 mm high.

Shell composed of a dark thick outer layer and a light thick central layer, each consisting of numerous lamellae; and a very thin innermost nacreous layer; each layer of uniform thickness over all parts of the shell.

Surface markings very distinctive, consisting of numerous strong wrinkles concentric with the apex, becoming finer near the apex; wrinkles covered with minute pustules, which become very prominent near the margin; natural gray of shell covered with patches of red, orange and purple.

Plates arranged in a graduated series increasing in size outward from a linear margin, which lies on the apical side of the plates.

Remarks.—The individual plates of *K. varigata* are extremely abundant in the Bonneterre and fortunately 10 or more specimens showing the plates grouped together have been obtained. The original shell material is perfectly preserved, retaining the natural colors and all the details of the structure.

The systematic position of the form is regarded as very questionable. The plates are similar to the many isolated plates from the Cambrian and Ordovician that have been variously referred to the chitons or the barnacles.[1] However, all the nearly complete tests of these described forms

[1] T. H. Withers seriously questions the veracity of such conclusions—Withers, T. H., *1915*, Some Paleozoic fossils referred to the Cirripedia: Geol. Mag., n. s., dec. 6, vol. 2, pp. 112–123.

show evidences of imbricating plates and a test structure unlike that of the Bonneterre specimens.

Though *Kinsabia varigata* is probably not related to the true barnacles, to which it shows no similarity, the new genus has been questionably referred to the Cirripedia because that is the group to which all the most similar-appearing plates have been referred, and is the group to which any paleontologist working with such material will first refer. It is hoped that the future discovery of the complete or nearly complete test of *Kinsabia varigata* will reveal the true relationships of the genus.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21, 76.22, 76.23, 76.24, 76.25, 76.29, 76.33, 76.34, 76.36, 76.37, 76.38, 82.12, 82.13, 82.14, 82.15, 82.18, 82.19, 82.20, 82.21, 82.22, 82.23, 82.24, 82.25.

Repository.—Holotype, largest fragment, U.S.N.M. 98719, locality 76.36; paratype, U.S.N.M. 98720, locality 82.12; unfigured paratypes, U.S.N.M. 98721, locality 82.22.

Class ARACHNIDA
Subclass MEROSTOMATA
Plate 2, figure 12

Fragments of a thin chitinous test composed of scales of varying sizes, roughly hexagonal in shape, occur in the collection. The largest of these scales is 1 mm in width. The markings on the scales consist of a small central boss and a surrounding flat area covered with what appear to be hexagonally arranged growth lines. The outer surface of the test is dark gray and covered with minute granules; the inner surface is smooth with a high lustre.

The character of the chitinous test suggests a relationship of the forms represented by these fragments to the Merostomata, though the fragments are too small to give any idea as to the shape and structure of the entire carapace of the animal.

EXPLANATION OF PLATE 5

FIGS. *1–7—Norwoodina appalachia* (Resser). *1–3*, Plesiotype; dorsal, side and front views of a nearly complete cranidium, U.S.N.M. 98783; *1, 2*, ×6, *3*, ×3, loc. 76.20. *6*, Plesiotype, a broken cranidium, U.S.N.M. 98783a, ×5, loc. 76.20. *7*, Plesiotype, cranidium with frontal border broken off, U.S.N.M. 98784, ×5, loc. 76.21. *4, 5*, Plesiotype, a small pygidium, U.S.N.M. 98784a, ×10, loc. 76.21. (p. 49)

8–11—Norwoodina tunda Lochman, n. sp. *8–10*, Holotype; dorsal, side and front views of a well-preserved cranidium, U.S.N.M. 98782, ×5, loc. 76.20. *11*, Paratype, a small cranidium, U.S.N.M. 98926, ×6, loc. 76.21. (p. 50)

12–14—Norwoodina tenera (Walcott). *12*, Plesiotype, a small cranidium, U.S.N.M. 98779a, ×5. *13, 14*, Plesiotype; dorsal ×5, and side view ×6, of a larger cranidium, U.S.N.M. 98779, both loc. 76.20. (p. 50)

15, 16—Norwoodina tenera cuneifera Lochman, n. var. Holotype; dorsal and side views of well-preserved cranidium, U.S.N.M. 98781, ×5, loc. 76.20. (p. 51)

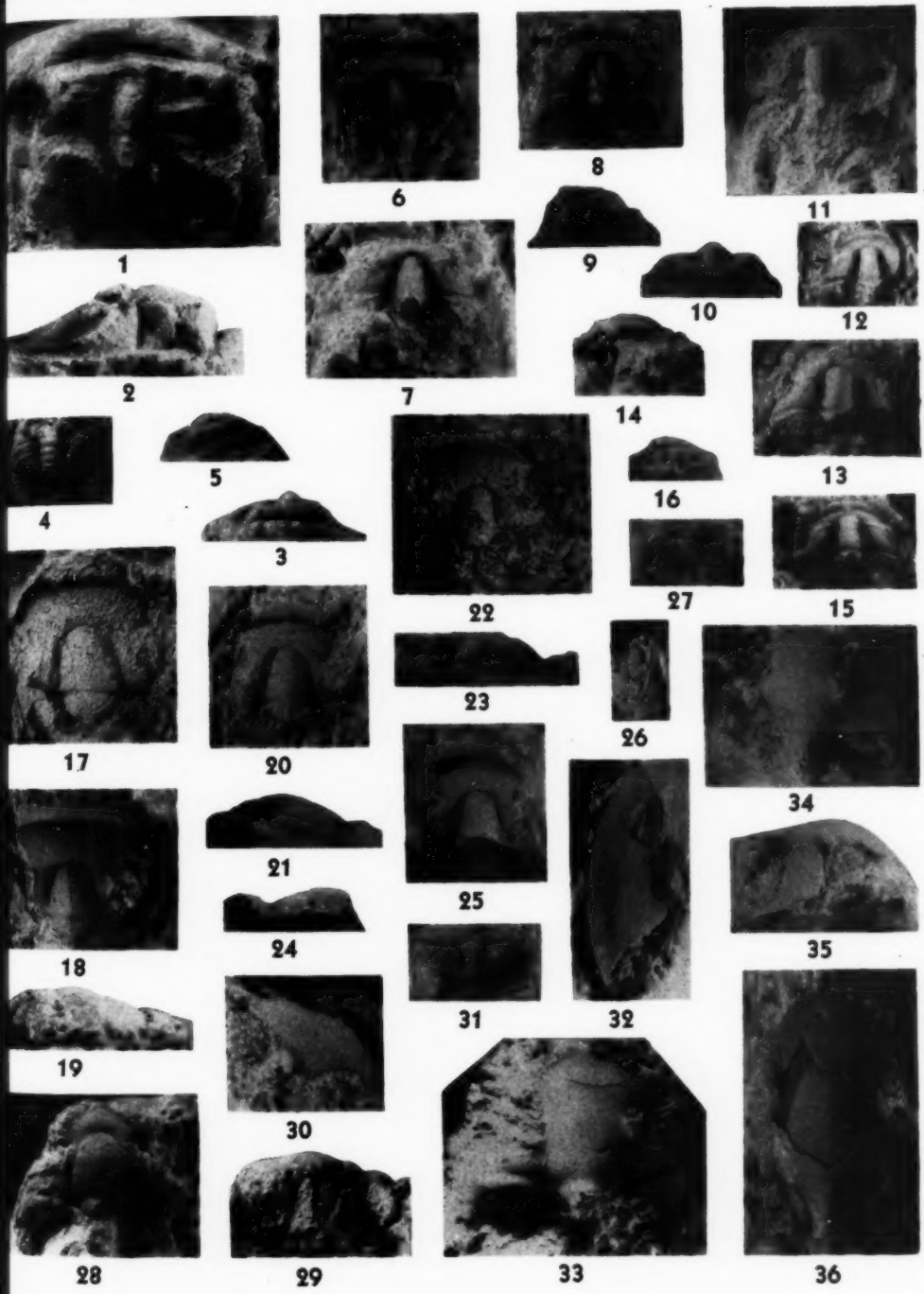
17–21—Norwoodia fillia Lochman, n. sp. *18, 19*, Holotype; dorsal and side views of well-preserved cranidium, U.S.N.M. 98774, ×6, loc. 76.37. *20, 21*, Paratype; dorsal and side views of cranidium, U.S.N.M. 98775, ×5, loc. 82.19. *17*, Paratype; dorsal view of a weathered cranidium showing inner surface of test, U.S.N.M. 98927, ×5, loc. 82.22. (p. 45)

22, 23—Norwoodia quadrata (Whitfield). Holotype; dorsal and side views of Whitfield's type, Univ. of Calif. 1221, ×6, Dresbach formation, Eau Claire member, Eau Claire, Wisconsin. (p. 46)

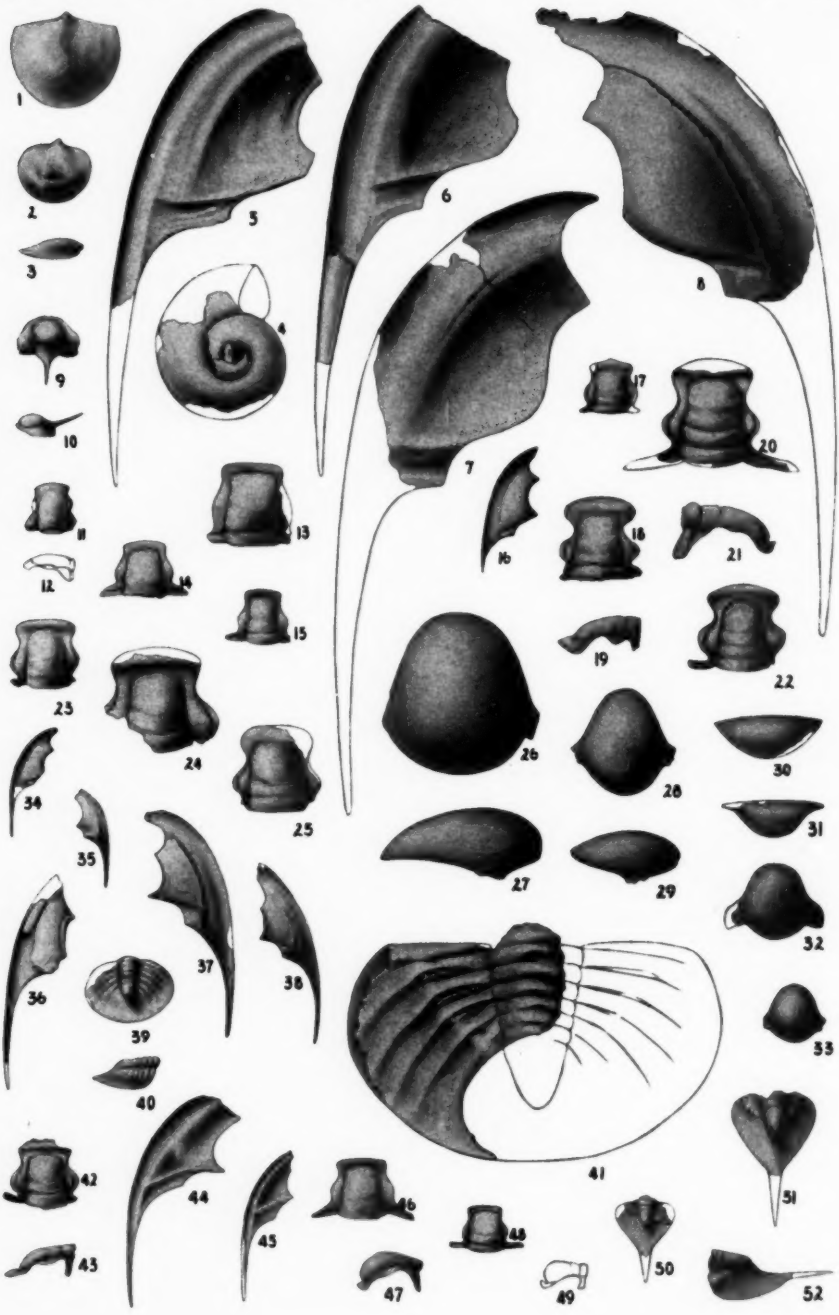
24–27—Norwoodia bonneterrensis Lochman, n. sp. *24, 25*, Holotype; side and dorsal views of best-preserved cranidium, U.S.N.M. 98776, ×5, loc. 76.21. *26*, Paratype, a large broken curved genal spine assigned to this species, U.S.N.M. 98777, ×1, loc. 82.22. *27*, Paratype, a small pygidium, U.S.N.M. 98778, ×5, loc. 76.29. (p. 45)

28–30—Norwoodella saffordi (Walcott). *28, 29*, Plesiotype; dorsal and side views of a well preserved cranidium, U.S.N.M. 98770, ×4, loc. 76.37. *30*, Plesiotype, a free cheek, U.S.N.M. 98771, ×6, loc. 82.22. (p. 47)

31–36—Norwoodella halli Resser. *33*, Dorsal view of a large cranidium lost after the picture taken, showing size of posterolateral limbs and smooth outer surface of test, ×4. *34, 35*, Plesiotype, dorsal and side views of a young cranidium with outer surface, U.S.N.M. 98767, ×6, loc. 76.25. *36*, Plesiotype, large broken cranidium showing furrows on inner surface of test, U.S.N.M. 98768, ×6, loc. 76.26. *31*, Plesiotype, pygidium associated with cranidium, figure *33*, U.S.N.M. 98767b, ×2, loc. 76.25. *32*, Plesiotype, a free cheek, U.S.N.M. 98769, ×6, loc. 82.19. (p. 47)



Lochman, Upper Cambrian Fossils



Stauffer, Upper Cambrian Fossils

Though only six fragments from two localities are known, the scarcity of the form in the fauna may be due to the frangibility of its carapace.

Occurrence.—Upper Cambrian, Bonneterre dolomite (*Cedaria* zone), at localities 76.20, 76.21.

Repository.—Figured specimen, U.S.-N.M. 98718, locality 76.20.

REFERENCES

1. BRIDGE, JOSIAH, *1937*, The correlation of the Upper Cambrian sections of Missouri and Texas with the section in the Upper Mississippi Valley: *U. S. Geol. Survey, Prof. Paper* 186-L, p. 234.
2. BUCKLEY, E. R., *1908*, Geology of the disseminated lead deposits of St. Francois and Washington Counties, Missouri: *Missouri Bur. Geology and Mines*. 2d ser., vol. 9, pt. 1, pp. 26–32.
3. DAKE, C. L., *1930*, The geology of the Potosi and Edgehill quadrangles, Missouri: *Missouri Bur. Geology and Mines*, 2d ser., vol. 23, p. 61.
4. JAEKEL, O., *1909*, Ueber die Agnostiden: *Deutsche geol. Gesell., Zeitschr*, Bd. 61, p. 380.
5. NASON, F. S., *1901*, The geological relations and age of the St. Joseph and Potosi limestones of St. Francois County, Missouri: *Am. Jour. Sci.*, 4th ser., vol. 12, p. 360.
6. RAW, FRANK, *1927*, Ontogeny of the trilobites: *Am. Jour. Sci.*, 5th ser., vol. 14, p. 140.
7. RESSER, C. E., *1937*, Third contribution to nomenclature of Cambrian trilobites: *Smithsonian Misc. Coll.*, vol. 95, no. 22, p. 27.
8. ——, *1938*, Fourth contribution to nomenclature of Cambrian fossils: *Smithsonian Misc. Coll.*, vol. 97, no. 10, p. 34; *a*, p. 36; *b*, p. 33.
9. ——, *1938*, Cambrian system (restricted) of the Southern Appalachians: *Geol. Soc. America, Special Paper* 15, p. 88.
10. TWENHOFEL, W. H., RAASCH, G. O., and THWAITES, F. T., *1935*, Cambrian strata in Wisconsin: *Geol. Soc. America, Bull.*, vol. 46, p. 1695.
11. WALCOTT, C. D., *1916*, Cambrian trilobites: *Smithsonian Misc. Coll.*, vol. 64, no. 3, pl. 28, figs. 3b, 3c.
12. ——, *1912*, Cambrian Brachiopoda: U. S. Geol. Survey, Mon. 51, pt. 2, pl. 53, fig. 4f.
13. WARBURG, ELSA, *1925*, Trilobites of the *Leptaena* limestone: *Upsala Univ., Geol. Inst., Bull.*, vol. 17, p. 74.
14. WELLER, STUART, and ST. CLAIR, STUART, *1928*, Geology of Ste. Genevieve County, Missouri: *Missouri Bur. Geology and Mines*, 2d ser., vol. 22; *a*, p. 45; *b*, p. 37; *c*, p. 42; *d*, p. 37.

NOTE: Submitted to The Johns Hopkins University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Manuscript received by the Editor August 12, 1939.

EXPLANATION OF PLATE 6

The Van Oser fauna, Merriam Junction, Minnesota

FIG. *1*—*Eoorthis* sp. ×2. (p. 55)
2, 3—*Orusia* sp. ×1. (p. 55)
4—*Dirhachopea* sp. ×2. (p. 55)
5–8—*Calvinella* sp. ×1. (p. 55)
9, 10—*Euptychaspis* sp. ×2. (p. 55)
11–15—*Plethopeltis* sp. *11, 12*, ×1; *13, 14, 15*, ×2. (p. 55)
16, 17—*Saukia* sp. ×1. (p. 56)
18–25—*Saukiella* sp. *18, 19, 24, 25*, ×1; *20–23*, ×2. (p. 56)
26–33—*Stenopilus* sp. *26–29, 32, 33*, ×2; *30, 31*, ×1. (p. 56)
34–45—*Tellerina* sp. ×1. (p. 56)
46–49—Trilobite, new genus? a, ×2. (p. 56)
50–52—Trilobite, new genus? b, ×1. (p. 56)

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 54–56, PL. 6, JANUARY, 1940

FAUNA OF THE VAN OSER BEDS

CLINTON R. STAUFFER
University of Minnesota, Minneapolis, Minn.

ABSTRACT—The Van Oser beds consist of not more than about 20 feet of coarse white to yellowish sandstone, most of whose grains are reconstructed quartz crystals. These beds form the upper part of the Jordan sandstone and are overlain disconformably by the Oneota dolomite in both the Minnesota and the St. Croix valleys. Along Van Oser Creek, near Merriam Junction, Minn., they contain a trilobite fauna characterized by an abundance of *Tellerina* and *Saukiella*, together with other forms suggestive of the lower Jordan or Norwalk fauna. Although probably new species, they are not named because of their fragmentary condition.

THE JORDAN sandstone is the latest formation of the St. Croixian series (Upper Cambrian) in Minnesota. Its upper part may consist of coarse-grained massive sandstone beds, particularly along the Minnesota and the St. Croix Rivers in Minnesota. These are the Van Oser beds. Except in a few places where remnants of other formations intervene, this sandstone in both of these regions is succeeded abruptly by the thick-bedded Oneota dolomite, and the contact thus formed is a marked disconformity. When Winchell discovered this coarse-grained sandstone along Van Oser Creek at Merriam Junction he recognized it as part of the sandstone then being quarried at Jordan and included it in the same formation.[1]

The Van Oser beds appear to continue downward into the more typical Jordan without a break. They may have a thickness of as much as 20 feet and are largely composed of coarse angular grains of quartz, which range from colorless to pale pink. In the upper part these grains are, in fact, reconstructed crystals of quartz, in some of which the rounded sand grains may still be seen. Although the exposed surfaces of the Van Oser beds are often thoroughly case-hardened, so loosely cemented is this sandstone beneath the crust that a blow of the hammer causes a block to crumble into loose sand.

The Van Oser beds generally have been regarded as barren of organic remains and probably the final emergent stage from the Cambrian sea. However, trilobite moulds were found in a quarry of the Minnesota Quartz Company in the high-lying outcrops just south of Van Oser Creek by Mr. A. P. Tabor, mining geologist, who immediately reported his find to the department of Geology at the University of Minnesota. A thorough search of the quarry was then made and this has been repeated at intervals over several years. The results have not been very satisfactory, but they have yielded an accumulation of fragments representing about a dozen genera and perhaps twice as many species. Great difficulties have been experienced in handling and transporting the fossils from the quarry. Many specimens crumbled while being packed, others actually blew away, grain by grain, while waiting to be packed, and still others fell into loose sand on the journey to the laboratory. All of it has had to be treated with a hardening solution to make it available for study. If there seemed to be any hope of obtaining better material from this horizon in Minnesota, the specimens so far collected would hardly be worth figuring or discussing, but it is doubtful whether even much additional material of any kind can be obtained. Much depends on the extent to which future quarrying is carried and on the interest of the men removing the sand.

The fragments indicate that the fauna is surprisingly large. It includes brachiopods, gastropods, and trilobites, many of which are represented merely by fragments seen in the field or that were too poorly preserved for even generic identification. Illustrations

[1] Winchell, N. H., *1874, Minnesota, Geol. and Nat. History Survey, 2nd Ann. Rept.*, pp. 148, 149.

of much of the fauna were sent to various persons interested in the Upper Cambrian of North America, from whom much help was received. Those who have contributed in this manner include Doctors C. E. Resser, B. F. Howell, Brookes Knight, Donald Duncan, Christina Lochman and W. H. Twenhofel. Had it not been for the assistance thus given, the approximate identifications and brief notes on the specimens probably would not have been submitted for publication. The author is much indebted to those named but assumes full responsibility for the statements that have been made in this paper. The fauna is characterized by the trilobite genera *Tellerina* and *Saukiella*, which tie it very definitely to other St. Croixian faunas of Minnesota and adjacent states. The presence of one or two specimens of *Euptychaspis* with these led Dr. Christina Lochman to pronounce it the typical *Euptychaspis-Saukiella* fauna, which recently has been found at several other localities in the Mississippi Valley.

NOTES ON THE FAUNA

The following tentative notes on the fauna may be useful, although they are subject to revision when other specimens are found. Many of those now in the collection are too poor for illustration or discussion. Those figured may therefore be considered as representative of the fauna, but by no means all the species.

BRACHIOPODA

The Brachiopoda may be fairly abundant in this fauna, as small unidentifiable fragments have been observed here and there in the sandstone. Only two are figured.

EOORTHIS? sp.
Plate 6, figure 1

Small shell, with straight hinge line nearly or quite equal to greatest width. Beak small and prominant over a low cardinal area. Surface markings not preserved.

ORUSIA? sp.
Plate 6, figures 2, 3

Shell small, subcircular, with relatively short hinge line and rounded cardinal extremities. Beak small and curving slightly over delthyrium. Lenticular cross section. Surface markings not preserved.

GASTROPODA

The Gastropoda are probably rare as only a single specimen was found.

DIRHACHOPEA sp.
Plate 6, figure 4

Shell dextral, with a depressed spiral probably of three or four, possibly more, expanding coils. A wide flattened umbilicus. Outer margin or periphery narrow, possibly keeled. Cross section more or less heart-shaped, which may be the shape of aperture. Surface probably smooth except for faint growth lines.

TRILOBITA

The trilobites make up a very large proportion of the whole fauna. In certain places they are relatively abundant. There may be several dozen species. These appear to belong to seven or eight genera, several of which may be undescribed.

CALVINELLA sp.
Plate 6, figures 5–8

A number of rather large free cheeks are believed to belong to this genus. The free cheek shows a wide, thick border with a slender, pointed genal spine. The facial suture seems to cut out nearly midway between the axial lobe and genal spine. Its curvature suggests a large compound eye of moderate convexity. On some of the surfaces there is a suggestion of roughness, which may be caused by papillae. There are probably several species represented in the fauna.

EUPTYCHASPIS sp.
Plate 6, figures 9, 10

Two drawings of the same specimen represent a fragmentary cranidium showing a prominant glabella enlarged in front and with axial furrows rather faintly shown. Fixed cheeks broad. A prominant spine extends backward from the occipital ring or posterior segment of the glabella.

PLETHOPELTIS sp.
Plate 6, figures 11–15

Several cranidia are represented by fairly

good specimens that appear to belong to this genus. The glabella is low, convex, with nearly straight sides; occipital ring well-developed, but remainder of glabella nearly smooth and separated from fixed cheeks by relatively deep furrows. Palpebral lobes small, anterior rim narrow; posterior limbs short. Two species may be represented.

SAUKIA sp.
Plate 6, figures 16, 17

A cranidium and one or two free cheeks that are fairly well preserved but perhaps belong to different species are among the specimens that may belong to this genus. The glabella is nearly straight, rectangular, and with four rings or segments showing, the two anterior probably being fused. Palpebral lobes long and rather narrow. Free cheek relatively large, convex, and with slender, sharp genal spine.

SAUKIELLA sp.
Plate 6, figures 18–25

Cranidia fairly common, representing two or three species probably belonging to this genus. Cranidium with prominent dorsal furrows, slightly concave at upper end of prominent palpebral lobes, eyes long, with the posterior at or behind occipital furrow, posterior limb narrow. Glabella with four to five segments showing, the furrows of which are nearly straight.

STENOPILUS sp.
Plate 6, figures 26–33

Glabella and pygidia probably all belonging to one species. Glabella large, smooth, oval, greatest convexity towards posterior, where it appears to overlap junction with thorax. Pygidium small, short, highly convex, and without trilobation.

TELLERINA sp.
Plate 6, figures 34–45

This is probably one of the more abundant species. It seems to be represented by cranidia, free cheeks, and pygidia that may belong to half a dozen different species. The cranidia have moderately convex glabella, which have a broad occipital ring and one or two other rings showing. Glabella tapering slightly towards anterior and separated from front by a moderate brim with convex margin. Palpebral lobes narrow and long. Visual surface of eye about half as long as glabella. Free cheek convex, with a thickened margin of moderate width and a long, slender genal spine. Pygidia strongly segmented, with six or seven segments showing, and with a broad flattened margin, on which the pleural ribs tend to disappear.

NEW GENUS? a
Plate 6, figures 46–49

Several cranidia suggest somewhat *Saukiella*, but the glabella is more prominent and convex, the palpebral lobes poorly developed, and the eyes small. It has been suggested by several of those who have seen the illustrations that these specimens may belong to a new genus.

NEW GENUS? b
Plate 6, figures 50–52

This includes several specimens of pygidia probably belonging to a single species. These pygidia are subtriangular in outline, with strongly developed axis and obliquely ribbed convex pleural lobes that end in a plain margin, except at posterior, where a strong spine extends backward. These specimens suggested some undescribed forms that have been found recently in the Ozarkian.

NOTE: Presented before the Paleontological Society December 30th, 1938. Manuscript received by the Editor January 13, 1939. This contribution is made possible through the research funds of the Graduate School, University of Minnesota.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 57–67, PLS. 7, 8, JANUARY, 1940

UPPER DEVONIAN RUGOSE CORALS OF THE NEVADA LIMESTONE

ERWIN C. STUMM
Oberlin College, Oberlin, Ohio

ABSTRACT—The paper presents a systematic description of the rugose corals occurring in the upper 500 feet of the formation from sections in the Eureka and White Pine mining districts. Species described from this horizon by F. B. Meek are revised. The species *Chonophyllum infundibulum* (Meek), *Synaptophyllum fasciculum* (Meek), *Phillipsastraea woodmani* (White), and *Phillipsastraea verrilli* (Meek) are illustrated. Two new species of *Diversophyllum*, one of *Tabulophyllum*, two of *Macgeea*, one of *Disphyllum*, and three of *Phillipsastraea* are described. Unidentified species of *Diversophyllum*, *Characterophyllum*, *Ptenophyllum*, and *Prismatophyllum* are illustrated.

THE NEVADA limestone averages approximately 5000 ft. in thickness and is exposed in many places in east-central Nevada. The basal 2430 feet of the formation is of Middle Devonian age. On the basis of the presence of species of *Stringocephalus* at this horizon C. W. Merriam has placed the beds above this level in the Upper Devonian and is proposing a new formation name for them. For a distance of 1800 feet above the *Stringocephalus* horizon the beds are not as well exposed and do not carry a large fauna, but the beds above this, comprising the upper 500 feet of the formation, carry a large and typical Upper Devonian fauna. This horizon is exposed in several places in the Eureka and White Pine mining districts. In the Eureka district the section at Devil's Gate, 7 miles northwest of the town of Eureka on U. S. highway 50, shows a good exposure of the upper 500 feet of the formation. According to C. W. Merriam (1937, p. 285), the coral fauna in this section occurs in a limestone bed about 260 feet from the top of the formation in association with *Hypothyridina emmonsi*. This horizon is also exposed in Yahoo Canyon, just south of Devil's Gate. In the White Pine mining district these beds occur on Treasure, Babylon and Argyle Hills.

With the exception of the coral fauna the most characteristic fossils of the upper 500 feet of the formation are *Productella lachrymosa*, *Pugnax pugnus*, *Spirifer engelmanni*, *Spirifer whitneyi*, *Martinia nevadensis*, *Hypothyridina emmonsi*, *Athyris angelica*, *Leiorhynchus laura*, *Leiorhynchus sinuatus*, *Grammysia minor*, and *Mytilarca chemungensis*.

The coral fauna of these beds is known as the "*Pachyphyllum*" assemblage. Many of the species herein described are present in the Martin limestone of Arizona, the Threeforks shale in Wyoming, Montana, and Idaho, and in the Upper Devonian limestones in British Columbia, Alberta, the Mackenzie Valley, and in southeastern Alaska. The coral assemblage also shows a marked resemblance to those found in the Upper Devonian "Hackberry" and Shellrock groups of Iowa.

The corals in the Middle Devonian portions of the Nevada limestone (see Stumm, 1937, and 1938) have a more restricted occurrence but are believed to be present in the Devonian beds in the Inyo Mountains and in the Kennett formation in the Klamath Mountain region. Their presence will probably be found in the Jefferson limestone of Idaho, Wyoming, and Montana, and also in the Middle Devonian limestones in western Canada and Alaska.

I wish to thank the United States Geological Survey and the Department of Geology of the United States National Museum for the loan of the specimens on which this paper is based. I am also indebted to the Department of Geology of Princeton University for furnishing the necessary equipment and financial assistance for the preparation of this work.

SYSTEMATIC DESCRIPTIONS

Genus DIVERSOPHYLLUM Sloss, 1939

Diversophyllum SLOSS, *1939*, Jour. Paleontology, vol. 13, no. 1, pp. 65–66.

Genotype.—By original designation, *Zaphrentis traversensis* Winchell, 1866.

DIVERSOPHYLLUM COMPRESSUM Stumm, n. sp. Plate 7, figure 1; plate 8, figures 1 a–c

External features: The holotype is a simple, ceratoid coral that is laterally compressed so that the diameter varies from 2 to 3 cm at the calyx. The proximal end of the specimen is missing and the total remaining length is 3.5 cm. Evidence from fragmentary paratypes indicates that the normal length is about 6 cm. The epitheca is heavy and roughly annulated, giving the appearance of a vertical series of invaginated calyxes. Vertical interseptal ridges are very faint. The calyx is bell-shaped and has a depth of 1.5 cm. The major septa extend from 1 to 2 mm above the calyx wall, and the alternate minor septa appear as faint striations between them.

Internal features: A transverse section of the holotype shows 68 smooth septa, which extend axially from a narrow peripheral stereozone 1.5 mm in diameter. The major septa are wedge-shaped, being almost 1 mm in diameter at their peripheral ends. They become attenuated as they approach their axial terminations, which are from 1 to 3 mm from the center of the corallite. The alternate minor septa consist of peripheral spines averaging less than 1 mm in length. Dissepiments are few, irregularly arranged, and strongly peripherally convex. In the longitudinal section the tabularium averages 1 cm in diameter and is composed of incomplete tabulae, which are either horizontal or irregularly disposed. The peripheral dissepimentarium varies from 3 to 6 mm and is composed of one or two rows of large, elongated dissepiments.

Remarks.—The great majority of these simple corals with radially arranged, unmodified septa, of which the minor are usually very short, have been placed in *Zaphrentis* or *Heterophrentis*. The possession of a relatively small number of irregularly placed dissepiments between the septa is common to both these genera and *Diversophyllum*, but the radial arrangement of the septa, the absence of a fossula or other modification of the primary septa, and the more complicated structure of the tabulae are structures that make *Diversophyllum* worthy of generic distinction.

In the transverse section *Diversophyllum compressum* is similar to *D. traversense*, especially the section illustrated by Sloss (op. cit., plate 11, fig. 22), but in the longitudinal section the tabulae of *D. compressum* have a more irregular arrangement, and the peripheral dissepimental zones are not as well developed.

Occurrence.—Upper 500 feet of the Nevada limestone, on the northeast spur of the high ridge between Yahoo and Reilley Canyons, just south of Devil's Gate, 7 miles northwest of Eureka, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98266a; paratype, U. S. Nat. Mus., 98266b.

DIVERSOPHYLLUM NEVADENSE Stumm, n. sp. Plate 7, figure 2; plate 8, figures 2a–b

Cyathophyllum corniculum WALCOTT, *1884* (not *Zaphrentis cornicula* (LESUEUR)), U. S. Geol. Survey, Mon. 8, p. 104.

External features: The holotype is a small ceratoid coral measuring 2 cm in length and expanding to a diameter of 1.6 cm at the distal extremity. The distal portion of the specimen is missing, but fragmentary paratypes show that the species becomes cylindrical during the later growth stages. The specimen is covered with a smooth epitheca on which horizontal growth annulations and vertical interseptal ridges are very faint.

Internal features: A transverse section shows 66 thin, radially arranged septa, all of which are slightly dilated at their peripheral ends. The major septa extend almost to the axis, and the alternate minor septa are very short, extending from 1 to 2 mm from the periphery. An outer zone of dissepimental tissue extends inward to the axial ends of the minor septa. Between this point and the axial ends of the major septa are occasional transverse structures which represent the cut edges of distally arched tabellae. In the longitudinal section the tabularium averages 1 cm in diameter and is composed of horizontal tabulae interspersed with short, distally arched tabellae.

The peripheral dissepimentarium averages 5 mm in diameter and is composed of small, axially directed dissepiments.

Remarks.—This species has an external appearance that is almost identical with that of *Zaphrentis cornicula*, but the smooth, unornamented septa and their radial arrangement are characters quite distinct from *Zaphrentis* s. s. The transverse section of *Traversophyllum nevadense* has an apparent similarity to that of *T. compressum* but can be distinguished from the latter by the more attenuated major septa and by the lack of a well-defined peripheral stereozone.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98267a; Paratype, U. S. Nat. Mus., 98267b.

DIVERSOPHYLLUM sp. undet.
Plate 7, figure 3; plate 8, figure 3

The specimen consists of the distal portion of a simple, ceratoid coral measuring almost 2 cm in length and with an average diameter of 1 cm. The calyx is erect, but the structure of its interior is unknown, as it is filled with a siliceous deposit.The epitheca possesses faint vertical striations and a few irregularly arranged protruding nodes. These nodes are rounded protuberances that extend outward about 2 mm and are separated by distances varying from 5 mm to 1 cm.

A transverse section cut just below the calyx shows about 64 thin, radially arranged septa projecting inward from a pronounced peripheral stereozone. The major septa extend almost to the axis and are slightly twisted at their axial ends. The minor septa are very short, appearing as peripheral spines less than 1 mm in length. Dissepimental tissue is present where the minor septa exist, but it is greatly obscured by the peripheral stereozone. Occasional cut edges of tabulae occur between the major septa in the axial region.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Specimen.—U. S. Nat. Mus., 98268.

Genus CHARACTOPHYLLUM Simpson, 1900

Charactophyllum SIMPSON, *1900*, N. Y. State Mus., Bull., vol. 39, no. 8, pp. 209–210.

Genotype.—By original designation, *Campophyllum nanum* Hall and Whitfield, 1873.

CHARACTOPHYLLUM sp. undet.
Plate 8, figure 4

The specimen is a fragment of a small ceratoid coral that yielded enough material for a transverse section. This section shows approximately 60 thin, radial septa of which the major average 8 mm in length and extend slightly more than one-half the distance to the axis. The alternate minor septa are about one-half as long. Peripherally convex dissepiments are numerous between the periphery and the axial ends of the minor septa.

Remarks.—The transverse section is very similar to those of *Charactophyllum nanum* from the Upper Devonian of Iowa illustrated by Fenton and Fenton (1924, pl. 1, figs. 2, 3). In the absence of more material, no specific designation of the Nevada form can be made.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Specimen.—U. S. Nat. Mus., 98269.

Genus GRYPOPHYLLUM Wedekind, 1922

Grypophyllum WEDEKIND, *1922*, Gesell. Förderung gesamt. Naturwiss. Marburg, Sitzungsber., pp. 8–13.

Genotype.—By original designation, *Grypophyllum denkmanni* Wedekind, op. cit.

GRYPOPHYLLUM GIGANTEUM Stumm
Plate 7, figure 4

Grypophyllum giganteum STUMM, *1937*, Jour. Paleontology, vol. 11, no. 5, p. 433.

The hypotype is the central portion of a large ceratoid coral with an average diameter of 5 cm. The specimen is partially silicified, and most external features are lacking. A longitudinally striated epitheca is preserved in a few places. Silicification of the specimen has produced a natural transverse section. This section shows a radial series of thin septa, of which the major extend almost to the axis and the minor are variable, some extending halfway to the

axis, others appearing as peripheral spines or as discontinuous septal crests. Dissepiments are numerous and are either peripherally convex or incomplete and irregularly disposed. These features are identical with those seen in the transverse section of *Grypophyllum giganteum* Stumm, op. cit., pl. 54, fig. 9a.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Hypotype.—U. S. Nat. Mus., 98270.

Genus TABULOPHYLLUM Fenton and Fenton, 1924

Tabulophyllum FENTON and FENTON, *1924*, Michigan Univ., Mus. Geol., Contr., vol. 1, pp. 30–31.

Genotype.—By original designation, *Tabulophyllum rectum* Fenton and Fenton, op. cit.

TABULOPHYLLUM CONTORTUM Stumm, n. sp.
Plate 7, figures 7a–b; plate 8, figures 5a–b

External features: The holotype is a simple, ceratoid coral measuring 6 cm in length with an average diameter of 3 cm. Weathering has removed the proximal point. The growth habit is very irregular, with many expansions produced by repeated rejuvenescence. The epitheca is heavy, with pronounced concentric growth wrinkles but lacking vertical interseptal striations except where worn thin or removed. A shallow calyx with gradually ascending walls shows about 88 septa, which are thin and radially arranged. The major septa extend almost to the axis and become irregularly disposed at their axial ends.

Internal features: In the transverse section there are 84 thin radial septa, of which the major extend to the axis, becoming irregular and slightly attenuated as they enter the tabularium. The alternate minor septa stop at the border of the tabularium. Dissepiments are fairly numerous and are horizontally disposed between the septa as far as the axial terminations of the minor septa. In the longitudinal section the tabularium is filled with closely set horizontal or distally convex tabellae. The dissepimentarium is usually obscure, in most places merging into the tabularium without a distinct boundary.

Remarks.—This species is very characteristic of *Tabulophyllum* in the structure of the calyx, the many growth expansions, the septal structure, and the incomplete tabellae. However, none of the species described by Fenton and Fenton possess the heavy, nonstriate epitheca that is characteristic of *T. contortum.*

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98271a; paratype, U. S. Nat. Mus., 98271b.

Genus PTENOPHYLLUM Wedekind, 1923

Ptenophyllum WEDEKIND, *1923*, Gesell. Beförd. gesamt. Naturwiss. Marburg, Sitzungsber. 1922, pp. 26, 27, 33, 34.

Genotype.—By subsequent designation of Wedekind (1924, p. 42), *Ptenophyllum simplex* Wedekind 1923, op. cit.

PTENOPHYLLUM, sp. undet.
Plate 8, figures 6a–b

The specimen is the central portion of a simple coral with an average diameter of 2 cm, on which all external features have been removed by weathering. Enough of the specimen was preserved so that excellent transverse and longitudinal sections could be obtained. The transverse section shows 72 radially arranged septa, of which the major extend to the axis and are greatly thickened by accretion of stereoplasm. Most of them become increasingly dilated as they enter the tabularium. The alternate minor septa are thin and less than one-half the length of the major. Dissepiments are very numerous, closely set, and peripherally convex. In the longitudinal section the tabularium averages 2 cm in diameter and is composed of relatively horizontal incomplete tabulae, which are broken up at different levels by the axial extent of the major septa. The peripheral dissepimentarium is composed of several rows of very fine axially arched dissepiments.

Remarks.—Wedekind established the Family Ptenophyllidae to comprise those rugose corals with septa thickened by stereoplasm, either complete, or intermittent in the form of carinae. The species illustrated by Wedekind under the genus *Ptenophyllum*, subgenus *Rhopalophyllum* comprise

those forms in which the greater amount of septal thickening is confined to the major septa. The transverse section of *Ptenophyllum* (*Rhopalophyllum*) *heterophyllum* (Edwards and Haime) illustrated by Wedekind (1924, p. 60, text. fig. 96) is very similar to that of the Nevada species.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Specimen.—U. S. Nat. Mus., 98272.

Genus MACGEEA Webster, 1889

Macgeea WEBSTER, *1889*, Am. Naturalist, vol. 23, pp. 710–711.

Genotype.—By original designation, *Pachyphyllum solitarium* Hall and Whitfield, 1873.

MACGEEA MAGNA Stumm, n. sp.
Plate 7, figures 5a–b; plate 8, figures 8a–c.

External features: The holotype is a simple, curved trochoid coral measuring 3 cm in length and expanding to a diameter of 2 cm at the calyx. The calyx is 1 cm in depth with a flat bottom and steeply ascending sides and shows 72 radially arranged septa, of which the major extend almost to the center and the minor are faint peripheral striae. All the septa continue over the rim of the calyx and are preserved as costae on the exterior of the coral. The epitheca is thin and only intermittently produced, but where it is present the costae are almost entirely obscured.

Internal features: In the transverse section there are 64 septa, all of which are dilated throughout the dissepimentarium. The minor septa terminate at the inner border of the dissepimentarium, but the major continue almost to the axis, becoming greatly attenuated in the tabularium. Occasional horizontal dissepiments can be seen in the peripheral region. A transverse section of an immature specimen shows even greater attenuation of the major septa in the tabularium and more abundant dissepiments in the peripheral region. In the longitudinal section the tabularium has an average diameter of 1 cm and is composed of horizontal or proximally convex tabulae that are usually complete. The dissepimentarium averages 0.5 cm in width and is composed of several rows of small axially convex dissepiments.

Remarks.—This species is very similar to *M. solitaria*, and immature specimens may be confused with it; but *M. magna* has a more pronounced distal expansion forming a much larger calyx, and the internal structure is distinct in that the major septa become much more attenuated axially, the tabulae are more complete, and the peripheral dissepimentarium is more highly developed.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98273a; paratypes, U. S. Nat. Mus., 98273b.

MACGEEA SUBCYLINDRICA Stumm, n. sp.
Plate 7, figures 6a–b; plate 8, figures 7a–b.

External features: The holotype is a small cylindro-ceratoid coral measuring 2 cm in length and with a maximum diameter of 11 mm. The calyx is restricted because of rejuvenescence and is filled with a secondary deposit of calcite, but that of a paratype is shallow, with gradually ascending walls and with radially arranged septa, of which the major extend to the center and the minor are only represented along the periphery. All the septa extend over the rim of the calyx to form fine, closely set rugae, between which vertical rows of horizontal dissepiments can be seen. The epitheca is very thin or lacking.

Internal features: In the transverse section there are 44 radially arranged septa, of which the major extend all the way to the axis, becoming twisted at their axial ends. They are dilated in the dissepimentarium and attenuated in the tabularium. The alternate minor septa are dilated at the periphery and attenuated at their axial ends, which mark the inner border of the dissepimentarium. Closely set series of fine dissepiments occur as far inward as the axial ends of the minor septa. In the longitudinal section the tabularium averages 8 mm in width and is composed of incomplete horizontal or distally arched tabulae. The dissepimentarium is only present where there

is a lateral expansion of the coral and is there composed of from one to five rows of small, axially arched dissepiments. At other points the tabularium extends to the peripheral wall.

Remarks.—The external appearance of this species is quite different from any other species referred to *Macgeea*. *M. subcylindrica* shows a strong tendency to bud through the calyx, thus preserving a relatively cylindrical form. The intermittent character of the dissepimentarium as seen in the longitudinal section is also a distinctive character.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98274a; paratype, U. S. Nat. Mus., 98274b.

Genus CHONOPHYLLUM Edwards and Haime, 1850

Chonophyllum EDWARDS and HAIME, *1850*, A monograph of the British fossil corals, pt. 1, p. 69.

Genotype.—By original designation, *Chonophyllum perfoliatum* Edwards and Haime, op. cit., = *Cyathophyllum plicatum* Goldfuss, 1826, pl. 18, fig. 5 only.

CHONOPHYLLUM INFUNDIBULUM (Meek)

Plate 7, figure 8; plate 8, figures 9a–b.

Ptychophyllum? infundibulum MEEK, *1877*, U. S. Geol. Survey 40th Par. Rept., vol. 4, pp. 28–29, pl. 2, figs. 1, 1a, 1b.

External features: The corallum is simple, patelloid, composed of a vertical series of invaginated calyxes that are reflexed peripherally. The average length is 2 cm, and the diameter at the calyx varies from 3 to 5 cm. The exterior is vertically striated, and these striations fuse at the proximal end and become gradually more separated as they approach the distal end, often being separated by as much as 1.5 mm at the distal extremity. The calyx is broad and flat except for a central pit measuring 1 cm in diameter and 5 mm in depth. The axial terminations of the minor septa are at the margin of the central pit, but the major continue almost to the axis.

Internal features: In a transverse section of a hypotype there are 42 septa that are strongly dilated peripherally, so that they form a stereozone occupying most of the reflexed portion of the corallum. The major septa extend almost to the axis, becoming very attenuated at their axial ends, and the alternate minor septa are almost as long. In the longitudinal section there is a central tabularium averaging 7 mm in diameter, which is composed of complete and incomplete tabulae, which are strongly distally arched. On either side is a vertical series of horizontal structures that represents the superposed calyxes formed of successive layers of septal stereozones.

Remarks.—A study of Meek's type specimens and a comparison of them with more recently collected specimens from the same horizon and locality indicates that his longitudinal section (Meek, 1877, op. cit., pl. 2, fig. 1) was not cut through the center, and that the structure he interpreted as a columella is composed of the cut axial ends of the major septa.

In placing this species in the genus *Chonophyllum*, the species *Chonophyllum infundibulum* Greene (1901, p. 49, pl. 18, figs. 6–10) becomes a homonym. Therefore, I propose for *Chonophyllum infundibulum* Greene, 1901 (not *Chonophyllum infundibulum* (Meek), 1877, the name *Chonophyllum greeni*.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Hypotypes, U. S. Nat. Mus., 98275.

Genus SYNAPTOPHYLLUM Simpson, 1900

Synaptophyllum SIMPSON, *1900*, New York State Mus., Bull., vol. 8, no. 39, pp. 212–214.

Genotype.—By original designation, *Eridophyllum arundinaceum* Billings, 1859.

SYNAPTOPHYLLUM FASCICULUM (Meek)

Plate 7, figure 9; plate 8, figures 10a–b.

Diphyphyllum fasciculum MEEK, *1877*, U. S. Geol. Expl. 40th Par., Rept., vol. 4, pp. 29–31, pl. 2, figs. 4, 4a, 4b.

The coralla are phaceloid, with individual cylindrical corallites averaging 5 mm in diameter. These corallites are connected at

various levels by lateral processes that are very similar to those produced in *Eridophyllum simcoense* Billings (1859, op. cit.). The individual corallites show from 34 to 36 radially arranged carinate septa, of which the major extend almost to the axis. They are dilated in the periphery and become more and more attenuated as they approach the axis. The alternate minor septa are thinner and are very short, never extending more than 1 mm from the periphery. A single row of dissepiments coincides with the axial terminations of the minor septa. In the longitudinal section the tabularium averages 3 mm in diameter and is composed of an axial series of horizontal tabellae, bordered by a periaxial series of distally arched tabellae. The peripheral dissepimentarium is composed of a single row of axially arched dissepiments.

Remarks.—This species is very similar to *Eridophyllum simcoense* Billings but is distinguished by the greater axial extent of the major septa and by the presence of a well-defined series of inclined, periaxial tabellae. The tabulae of *E. simcoense* are complete or incomplete but are not divided into an axial and periaxial series.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Holotype, U. S. Nat. Mus. 98276.

Genus DISPHYLLUM de Fromentel, 1861

Disphyllum DE FROMENTEL, *1861*, Introduction à l'étude des polypiers fossiles, p. 302.

Genotype.—By subsequent designation of Lang and Smith, 1935, *Cyathophyllum caespitosum* Goldfuss, 1826, pl. 19, fig. 2b.

DISPHYLLUM NEVADENSE Stumm, n. sp. Plate 7, figure 10; plate 8, figures 11a–b.

External features: The holotype is a phaceloid corallum composed of cylindrical corallites that vary from 6 to 8 mm in diameter. Their exteriors are vertically striated but do not show any pronounced transverse growth annulations. The calyxes are not preserved.

Internal features: In the transverse section there are from 36 to 40 thin, carinate septa, of which the major extend almost to the axis and the minor are about one-half as long. The major septa are slightly dilated near their peripheral ends. Dissepiments are common as far inward as the axial ends of the minor septa. In the longitudinal section the tabularium averages 5 mm in diameter and is composed of a central series of flat tabellae flanked on either side by a distally arched series of inclined tabellae. The dissepimentarium is composed of series of three or four rows of small axially arched dissepiments.

Remarks.—In the transverse section this species is similar to *Cyclindrophyllum panicum* (Winchell) as illustrated by Ehlers and White (1932), but in the longitudinal section the tabulae of *C. panicum* are farther apart and more complete. Externally *C. panicum* shows a well-developed series of growth annulations that are lacking in *D. nevadense*.

Occurrence.—Upper 500 feet of the Nevada limestone at Babylon Hill, White Pine mining district, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98277.

Genus PRISMATOPHYLLUM Simpson, 1900

Prismatophyllum SIMPSON, *1900*, New York State Mus., Bull., vol. 8, p. 218.

Genotype.—By original designation, *Cyathophyllum rugosum* Edwards and Haime (1851) = *Prismatophyllum prisma* Lang and Smith (1935, pp. 558–559).

PRISMATOPHYLLUM, sp. undet. Plate 8, figure 12

The specimen is a small fragment of a compound corallum, of which there was enough material for a transverse section. This section shows polygonal, usually hexagonal corallites that vary from 1.5 to over 2 cm in diameter. Epithecal walls are strong and usually straight. The septa average 40 in number in the individual corallites and are heavily carinate. The major septa extend all the way to the axis, and the alternate minor septa are almost as long, so that the tabularia a marked by the axial terminations of the minor septa average less than 3 mm in diameter.

Remarks.—The unusually long minor septa and the restricted tabularia are features that I have not seen in any other species of *Prismatophyllum*. More material will be necessary before a specific designation can be made.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Specimen.—U. S. Nat. Mus., 98278.

Genus PHILLIPSASTRAEA d'Orbigny

Phillipsastraea D'ORBIGNY, *1849*, Note sur des polypiers fossiles, p. 12.

Genotype.—By subsequent designation of Edwards and Haime, 1850, p. 71, *Astrea hennahi* Lonsdale, 1840; see Smith, 1917, p. 284.

PHILLIPSASTRAEA WOODMANI (White)

Plate 7, figure 11; plate 8, figures 13a–b.

Smithia woodmani WHITE, *1870*, Geol. of Iowa, vol. 1, p. 188.

Pachyphyllum woodmani, HALL and WHITFIELD, *1873*, N. Y. State Cab. Nat. Hist., 23rd Ann. Rept., p. 239, pl. 9, fig. 9.

Pachyphyllum woodmani, FENTON and FENTON, *1924*, Michigan Univ., Mus. Geol., Contr., vol. 1, pp. 46–47, pl. 7, figs. 1–3; pl. 8, fig. 2; pl. 9, figs. 11–12; pl. 10, fig. 3.

The hypotype is a portion of a hemispherical corallum that is composed of astraeoid corallites with confluent septa. The individual corallites vary from 1 to 2 cm in diameter. Dilation of the septa at the margin of the tabularia produces strong exsert rims that project as much as 4 mm above the dissepimentaria and the central pits. These exsert rims surrounding the tabularia vary from 5 mm to 1 cm in diameter. The minor septa terminate at this wall, but the major continue and stop just short of the axis. In the transverse section there are from 36 to 42 radially arranged septa in the individual corallites. They are either confluent with those of neighboring corallites or abut against them. All the septa become strongly dilated at the margin of the tabularium, and the minor septa stop here. The major septa, becoming very attenuated, continue to within 2 mm of the axis. Transverse dissepiments are common between the peripheral ends of the septa and the margin of the tabularium. In the longitudinal section the tabularia vary from 5 mm to 1 cm in width and are composed of a central series of horizontal tabellae bounded on either side by a series of inclined tabellae.

Remarks.—This species has usually been placed in the genus *Pachyphyllum*, but this genus, as shown by the genotype, *P. bouchardi*, differs from *Phillipsastraea* only in the larger size of the individual corallites. Most authors do not consider *Pachyphyllum* to be worthy of generic distinction. Belanski (1928, p. 174) has interpreted *Pachyphyllum* on the basis of *P. devoniense* Edwards and Haime (1851, p. 397) and his own species *P. websteri* (op. cit., pp. 171–174, text fig. p. 172), in which periph-

---

EXPLANATION OF PLATE 7

All figures natural size

FIG. *1—Diversophyllum compressum* Stumm, n. sp. View of the calyx of holotype. (p. 58)

2—Diversophyllum nevadense Stumm, n. sp. Side view of holotype. (p. 58)

3—Diversophyllum, sp. undet. Side view of the specimen showing protruding nodes. (p. 59)

4—Grypophyllum giganteum Stumm. Distal view of hypotype showing natural transverse section. (p. 59)

5a–b—Macgeea magna Stumm, n. sp. *5a*, Side view of holotype; *5b*, view of calyx of immature paratype. (p. 61)

6a–b—Macgeea subcylindrica Stumm, n. sp. *6a*, Side view of holotype; *6b*, calyx of paratype. (p. 61)

7a–b—Tabulophyllum contortum Stumm, n. sp. *7a*, Side view of holotype; *7b*, calyx of holotype. (p. 60)

8—Chonophyllum infundibulum (Meek). View of calyx of hypotype. (p. 62)

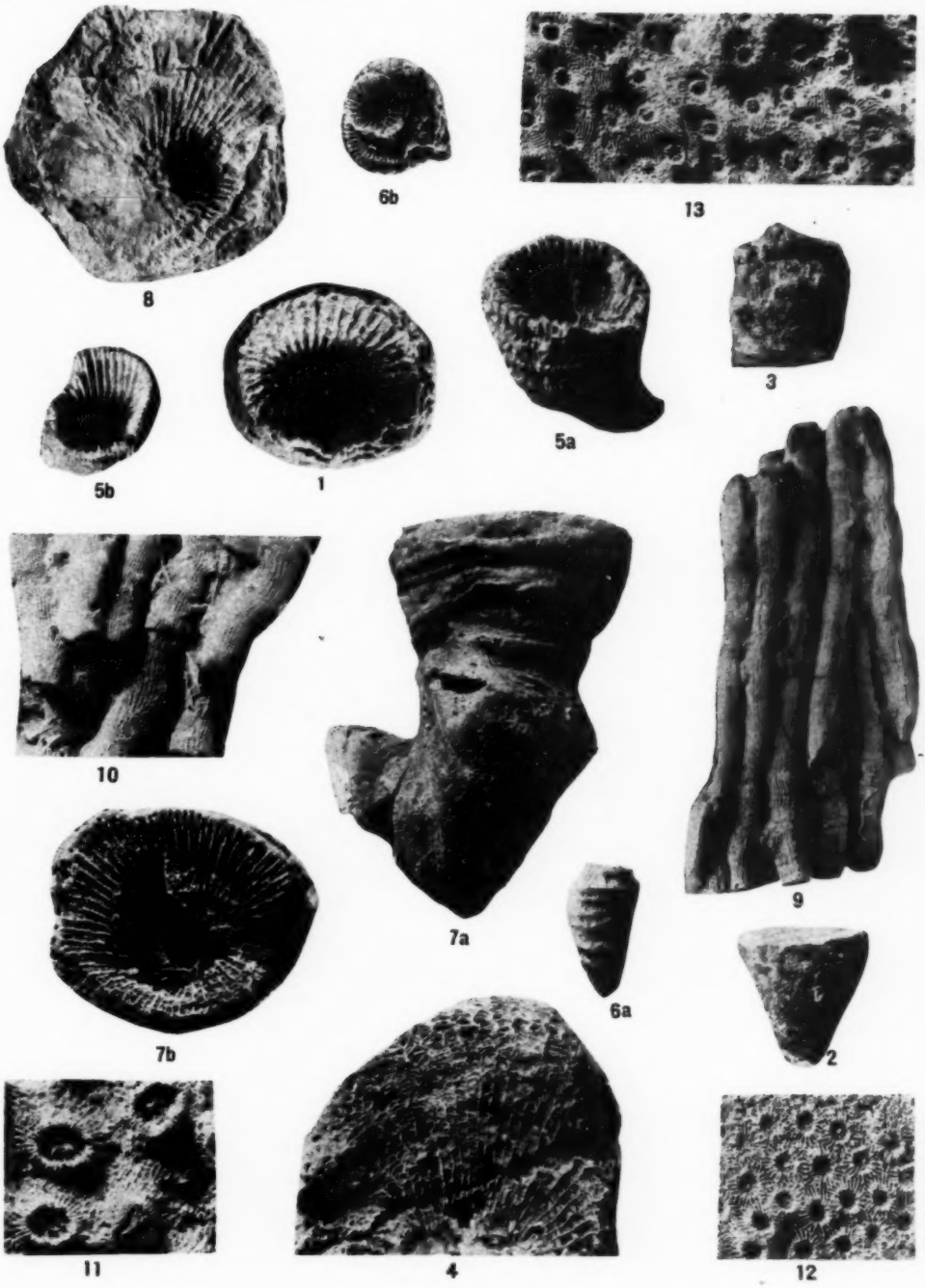
9—Synaptophyllum fasciculum (Meek). Side view of one of Meek's cotypes. (p. 62)

10—Disphyllum nevadense Stumm, n. sp. Side view of a portion of holotype. (p. 63)

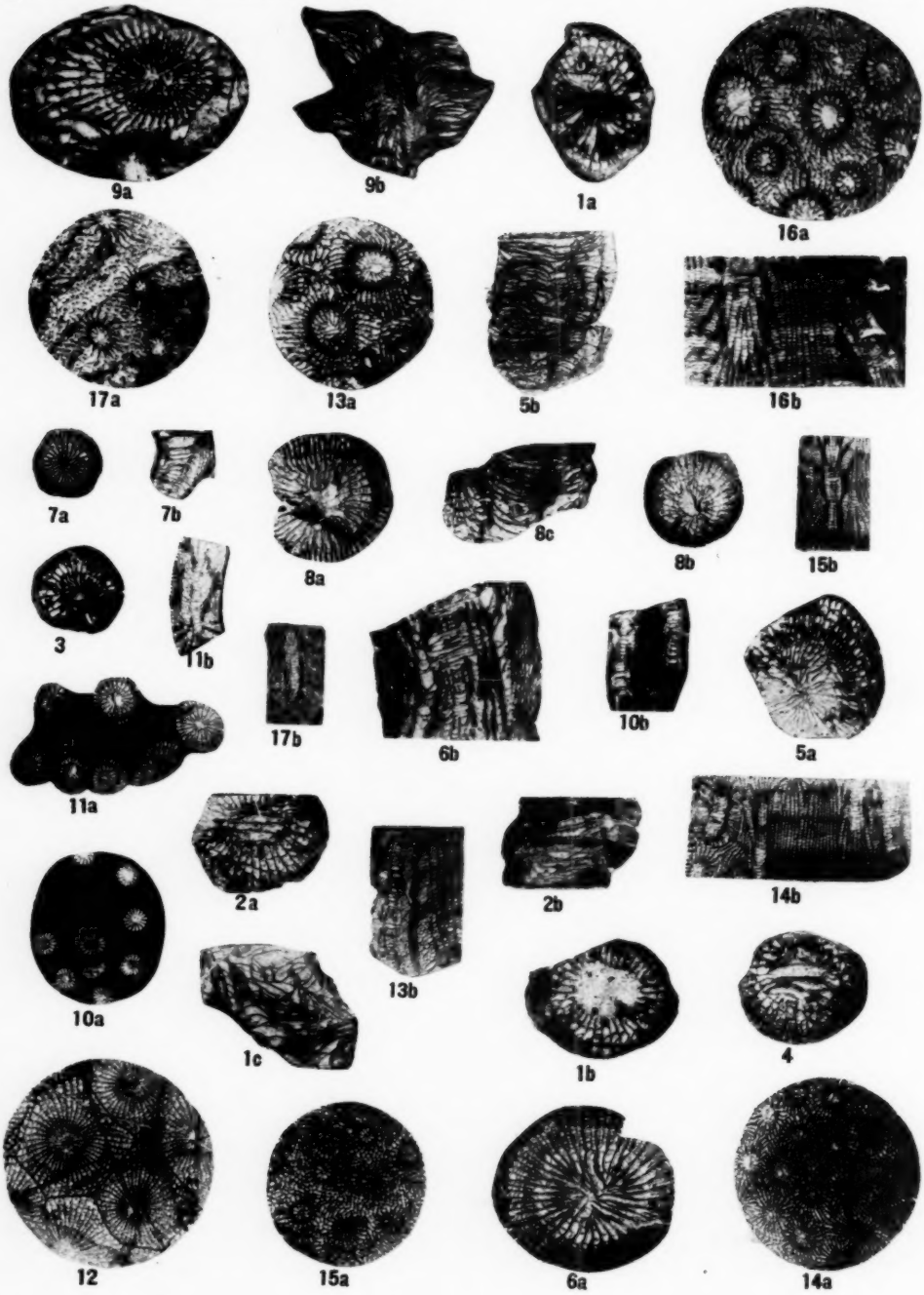
11—Phillipsastraea woodmani (White). Distal view of hypotype. (p. 64)

12—Phillipsastraea verrilli (Meek). Distal view of hypotype. (p. 66)

13—Phillipsastraea nevadensis Stumm, n. sp. Distal view of a portion of holotype. (p. 66)



Stumm, Devonian Corals



Stumm, Devonian Corals

eral retreat of the septa has caused the corallites to be separated by dissepimental tissue. Lang and Smith (1935, p. 555) show that this interpretation is untenable because peripheral septal retreat is not exhibited in the genotype of *Pachyphyllum, P. bouchardi* Edwards and Haime (1850 p. 68). In addition Lang and Smith claim that both septal confluence and peripheral septal retreat can be seen in the same colony of corallites at different stages of growth.

Occurrence.—Upper 500 feet of the Nevada limestone at Devil's Gate, 7 miles northwest of Eureka, Nevada.

Types.—Hypotype, U. S. Nat. Mus., 98279.

PHILLIPSASTRAEA BREVISEPTATUM Stumm, n. sp.

Plate 8, figures 16a–b.

External features: The holotype is a part of a large hemispherical corallum. Most of the external features have been removed by weathering, but the septal dilation at the margin of the tabularium indicate that the exsert rims are present on perfect specimens.

Internal features: The transverse section shows radiating septa whose peripheral terminations are not in contact with those of neighboring corallites. The intervening space varies from 1 to 4 mm and is occupied with dissepimental tissue, on which interrupted septal crests can be seen. The septa in the individual corallites average 32 in number and are all strongly dilated at the margin of the tabularium. The minor septa stop there, but the major continue in an attenuated form about half-way to the axis, where they stop abruptly, leaving an unoccupied space averaging 3 mm in diameter in the axial regions. The tabularia average 6 mm in diameter and are uniformly arranged so that their centers lie at an average distance of 1 cm apart. Dissepiments are common between the peripheral portions of the septa. In the longitudinal section the tabularium consists of horizontal complete and incomplete tabulae bordered on either side by a series of distally arched,

---

EXPLANATION OF PLATE 8

All figures natural size

FIGS. *1a–c—Diversophyllum compressum* Stumm, n. sp. *1a*, transverse section of holotype; *1b*, transverse section through calyx of a paratype; *1c*, longitudinal section of paratype. (p. 58)

2a–b—Diversophyllum nevadense Stumm, n. sp. *2a*, transverse section of holotype; *2b*, longitudinal section of paratype. (p. 58)

3—Diversophyllum, sp. undet. Transverse section of specimen. (p. 59)

4—Characophyllum, sp. undet. Transverse section of specimen. (p. 59)

5a–b—Tabulophyllum contortum Stumm, n. sp. *5a*, Transverse section of holotype; *5b*, longitudinal section of paratype. (p. 60)

6a–b—Ptenophyllum, sp. undet. *6a*, Transverse section of specimen; *6b*, longitudinal section of specimen. (p. 60)

7a–b—Macgeea subcylindrica Stumm, n. sp. *7a*, Transverse section of holotype; *7b*, longitudinal section of a paratype. (p. 61)

8a–c—Macgeea magna Stumm, n. sp. *8a*, Transverse section of a paratype; *8b*, transverse section of another paratype; *8c*, longitudinal section of a paratype. (p. 61)

9a–b—Chonophyllum infundibulum (Meek). *9a*, Transverse section of a hypotype; *9b*, longitudinal section of another hypotype. (p. 62)

10a–b—Synaptophyllum fasciculum (Meek). *10a*, Transverse section of hypotype; *10b*, longitudinal section of hypotype. (p. 62)

11a–b—Disphyllum nevadense Stumm, n. sp. *11a*, Transverse section of holotype; *11b*, longitudinal section of holotype. (p. 63)

12—Prismatophyllum, sp. undet. Transverse section of specimen. (p. 63)

13a–b—Phillipsastraea woodmani (White). *13a*, Transverse section of hypotype; *13b*, longitudinal section of hypotype. (p. 64)

14a–b—Phillipsastraea verrilli (Meek). *14a*, Transverse section of hypotype; *13b*, longitudinal section of hypotype. (p. 66)

15a–b—Phillipsastraea nevadensis Stumm, n. sp. *15a*, Transverse section of holotype; *15b*, longitudinal section of holotype. (p. 66)

16a–b—Phillipsastraea breviseptatum Stumm, n. sp. *16a*, Transverse section of holotype; *16b*, longitudinal section of holotype. (p. 65)

17a–b—Phillipsastraea occidens Stumm, n. sp. *17a*, Transverse section of holotype; *17b*, longitudinal section of holotype. (p. 67)

horseshoe-shaped dissepiments. These tabularia average 6 mm in width.

Remarks.—This species is similar to *Pachyphyllum devoniense* Edwards and Haime and to *P. websteri* Belanski in that they all show peripheral retreat of the septa. In *P. devoniense* the major septa extend all the way to the axis, and in *P. websteri* the septa do not extend peripherally beyond the dilated portions at the margins of the tabularia.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Holotype, U. S. Nat. Mus., 98280.

PHILLIPSASTRAEA VERRILLI (Meek)
Plate 7, figure 12; plate 8, figures 14a–b

Smithia verrilli MEEK, *1868*, Chicago Acad. Sciences, Trans., vol. 1, p. 83, pl. 11, figs. 7, 7a, 7b.
Acervularia pentagona MEEK, *1877* (not *Cyathophyllum pentagonum* GOLDFUSS), U. S. Geol. Survey 40th Par. Rept., vol. 4, pp. 31–32, pl. 2, figs. 5, 5a.
Acervularia pentagona WALCOTT, *1884* (not *Cyathophyllum pentagonum* GOLDFUSS), U. S. Geol. Survey Mon. 8, p. 105.

External features: The hypotype is a portion of a massive corallum on which the external characters are excellently preserved. The septa are radially arranged and very short, so that the tabularia lie with their centers at a uniform distance of 5 mm apart. The septa are not greatly dilated at the margins of the tabularia, and therefore they do not form prominent exsert rims. The tabularia vary from 2 to 3 mm in diameter, and are marked, as in the other species of *Phillipsastraea*, by the axial terminations of the minor septa. All the major septa continue to the axes, which are the centers of the central pits, from 1 to 2 mm below the margins.

Internal features: In the transverse section there are from 26 to 28 septa whose peripheral ends are either confluent with or abutting against those of neighboring corallites. From a point close to their peripheral ends until they reach the tabularia the septa are dilated; the point of greatest dilation being midway between their peripheral ends and the tabularia. The minor septa terminate at the tabularia, and the major, becoming very attenuated, continue from 1 to 2 mm into the tabularia, leaving an unoccupied space averaging 1 mm in diameter in the axial regions. Numerous horizontal dissepiments occur between the septa in the dissepimentaria. They are especially numerous around the margin of the tabularia. In the longitudinal section the tabularia are filled with horizontal or distally arched, complete and incomplete tabulae. These tabularia average 3 mm in diameter.

Remarks.—Meek misinterpreted the internal structure of the specimen he identified as *Acervularia pentagona* from the White Pine mining district. A polished section of Meek's type specimen does not show the zigzag peripheral walls between the corallites. The structure of the specimen is apparently identical with that of the hypotype herein illustrated.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Hypotype, U. S. Nat. Mus. 98281.

PHILLIPSASTRAEA NEVADENSIS
Stumm, n. sp.
Plate 7, figure 13; plate 8, figures 15a–b.

Smithia hennahi MEEK, *1877* (not *Astrea hennahi* LONSDALE), U. S. Geol. Expl. 40th Par., Rept., pp. 32–33, pl. 2, figs. 6, 6a.
Phillipsastraea verrilli LAMBE, *1901* (not *Smithia verrilli* MEEK), Contr. to Canadian Paleontology, vol. 4, part 2, pp. 167–168, pl. 14, figs. 5, 5a, 5b, 6.

External features: The holotype is a large portion of a massive hemispherical corallum on which the exsert margins of the tabularia of the individual corallites are prominent. These circular rims average slightly less than 3 mm in diameter and project from 1 to 2 mm above the general surface. The septa are twisted in the dissepimentaria and become dilated at the margin of the tabularia. There the minor septa terminate, and the major continue in the central pits to the axes. The peripheral extent of the septa varies in different corallites, so that the tabularia vary from 5 mm to over 1 cm apart.

Internal features: In the transverse section the septa average 24 in number and are twisted throughout the dissepimentaria. At their peripheral ends they are either confluent with or abutting against those of neighboring corallites. The septa dilate at the margin of the tabularia, and the minor septa terminate there, though the major

continue in an attenuated form to the axis. Horizontal dissepiments are common between the peripheral portions of the septa. Several crowded rows can be seen around the margin of the tabularium. In the longitudinal section the tabularia average 3 mm in width and are composed of complete and incomplete horizontal or distally arched tabulae.

Remarks.—*Phillipsastraea nevadensis* is very similar to *P. hennahi* Lonsdale, the genotype of *Phillipsastraea*, but is distinguished by the total absence of epithecal walls and by greater confluence of the septa. In *P. hennahi* traces of epithecal walls are found between the corallites, and very few of the peripheral ends of the septa are confluent with those of neighboring corallites. A transverse and longitudinal section of the genotype of *Phillipsastraea* can be seen in Smith, S., 1917.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Holotype, U. S. Nat. Mus. 98282.

PHILLIPSASTRAEA OCCIDENS Stumm, n. sp.

Plate 8, figures 17a–b.

External features: The holotype is a portion of a massive corallum on which the external characters have been removed by weathering.

Internal features: A transverse section shows radially arranged septa that dilate around the margins of the tabularia and disappear peripherally into a mass of structureless dissepimental tissue. At their peripheral ends the septa continue by means of isolated septal crests, by which their former extent can be traced. The septa rarely extend outward more than 5 mm from the tabularia. The tabularia average 3 mm in diameter, and the minor septa terminate there while the major continue about half-way to the axes, becoming very attenuated as they enter the tabularia. The centers of the tabularia vary from 8 to 12 mm apart and, as the septa extend peripherally about half that distance, the intervening spaces are occupied by disconnected septal crests on the dissepimental tissue. In the longitudinal section the tabularia average 3 mm in diameter and are composed of incomplete horizontal or distally arched tabulae, bounded on either side by a very small row of distally arched, horseshoe-shaped dissepiments.

Occurrence.—Upper 500 feet of the Nevada limestone at Treasure Peak, White Pine mining district, Nevada.

Types.—Holotype, U. S. Nat. Mus. 98283.

REFERENCES

BELANSKI, C. H., *1928*, The Shellrock stage of the Devonian of Iowa: *Am. Midland Naturalist*, vol. 11, no. 5.

BILLINGS, E., *1859*, On the fossil corals of the Devonian rocks of Canada West: *Canadian Jour.*, n. s., vol. 4, pp. 97–140.

EDWARDS, H. M., and HAIME, J., *1850*, A monograph of the British fossil corals: *Palaeont. Soc.*, pt. 1.

——, *1851*, Monographie des polypiers fossiles des terrains paleozoiques: *Mus. histoire nat. Paris, Archives*, vol. 5, p. 387.

EHLERS, G. M., and WHITE, T. E., *1932*, *Cylindrophyllum panicum* (Winchell) and *Cylinrophyllum hindshawi*, sp. nov., tetracoralla from the Traverse group of Michigan: *Michigan Univ., Mus. Paleontology, Contr.*, vol. 4, no. 4, pp. 93–100.

FENTON, C. L., and FENTON, M. A., *1924*, The stratigraphy and fauna of the Hackberry stage of the Upper Devonian: *Michigan Univ., Mus. Geology, Contr.*, vol. 1.

GOLDFUSS, G. A., *1826*, *Petrefacta Germaniae.*

GREENE, G. K., *1901*, *Contributions to Indiana Paleontology*, pt. 6.

HALL, JAMES, and WHITFIELD, R. P., *1873*, Descriptions of new species of fossils from the Devonian rocks of Iowa: *New York State Cab. Nat. History, Ann. Rept.* 23, pp. 223–239.

LANG, W. D., and SMITH, S., *1935*, *Cyathophyllum caespitosum* Goldfuss, and other Devonian corals considered in a revision of that species: *Geol. Soc. London, Quart. Jour.*, vol. 19, pp. 538–590.

LONSDALE, W., *1840*, *Geol. Soc., Trans.*, ser. 2, vol. 5, p. 697.

MERRIAM, C. W., *1938*, The position of *Hypothyridina emmonsi* in the Nevada Devonian (abst.): *Geol. Soc. America, Proc. for 1937*, p. 285.

SMITH, S., *1917*, *Aulina rotiformis*, gen. et sp. nov., *Phillipsastraea hennahi* (Lonsdale), and *Orionastraea*, gen. nov.: *Geol. Soc. London, Quart. Jour.*, vol. 72, p. 280.

STUMM, E. C., *1937*, The lower Middle Devonian tetracorals of the Nevada limestone: *Jour. Paleontology*, vol. 11, no. 5, pp. 423–443.

——, *1938*, Upper Middle Devonian rugose corals of the Nevada limestone: *Jour. Paleontology*, vol. 12, no. 5, pp. 478–485.

WEDEKIND, R., *1924*, Das Mitteldevon der Eifel, Theil 1: *Gesell. Beförd. gesamt. Naturwiss. Marburg, Schr.*, vol. 14, no. 3.

WINCHELL, ALEXANDER, *1866*, *The Grand Traverse region*, p. 90.

NOTE: Manuscript received by the Editor June 15, 1939.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 68–73, PLS. 9, 10, JANUARY, 1940

UPPER PALEOZOIC CEPHALOPODS FROM CENTRAL HUNAN, CHINA

KING KOO CHAO
Columbia University, New York City

ABSTRACT—In this paper five genera of cephalopods are described and illustrated. They include three genera of nautiloids—*Stroboceras*, *Coloceras*, and *Stenopoceras*—and two genera of ammonoids—*Imitoceras*, and *Hunanites*. The last is a new genus including two new species. The cephalopods came from Changlingpu, Siangtan, Central Hunan. They probably are of Shangssuan age of the Fengnian system. Though the geological age is still in doubt, they are very significant, because the Lower Carboniferous cephalopods have never been reported in China. All the geologic formations in the region from which these fossils come are discussed.

DURING his Hunan excursion in April 1937, Prof. C. Y. Hsieh of the National Peking University collected a great number of cephalopods near Changlingpu, Siangtan, Hunan, enroute to Shuikoushan, Changning, to study a lead-zinc deposit. These fossils are mostly excellent specimens. They expose their sutures but are completely ferruginated. According to Hsieh, they are found in shales intercalated with chert beds. Because the collection was made in a very short time, the geologic succession was not made clear enough.

As a result of the study of these fossils, it was found that they belong to three genera of nautiloids—*Stroboceras*, *Coloceras* and *Stenopoceras*—and two genera of ammonoids—*Imitoceras* [*Aganides*] and *Hunanites*. *Hunanites* is a new genus closely related to *Imitoceras*.

As few cephalopods have been described from the upper Paleozoic rocks in China, it is rather difficult to date their age. The nautiloids give little aid, because all of them represent genera ranging from Lower Carboniferous to Permian. Among the ammonoids, the new genus *Hunanites* gives no clue to the age. The only other genus is *Imitoceras* [*Aganides*]. It is from this genus that the age of these fossils is inferred. This genus ranges from Upper Devonian to middle Permian, though large forms are generally confined to Upper Devonian and Lower Carboniferous, the Pennsylvanian and Permian species being usually minute forms. *Hunanites* seems to be an offshoot of *Imitoceras* as indicated by the suture lines in the adolescent stage. It is highly ornamented. As the nautiloids represent genera that have never been reported from Devonian rocks, there is little possibility of their age being Devonian. Moreover rocks of Pennsylvanian and lower Permian ages in this region are limestones, but these fossils were collected from shales. Therefore, the writer is inclined to believe that the fossils are probably of Lower Carboniferous age.

The Fengnian or Lower Carboniferous rocks in Hunan were divided several years ago by Mr. C. C. Tien into four series. Their ages corresponding to the standard columns of China and Europe are as follows:

China	*Hunan*	*Europe*
Shangssuan	Tzemenchiao limestone	Viséan
Chiussuan	Tseshui coal series	Absent
	Shihtengtze limestone	
Kaolaohoan	Mengkungao limestone	Tournaisian

The top formation is believed to be the one from which these fossils came, for, according to Tien, it contains shales and sandstones in the lower part. Another important fact is that the Tsehui coal series contains hematite nodules, which were probably formed subsequent to the sedimentation of the strata. If so, it is reasonable to infer that the overlying rocks were infiltrated by the same iron solution. This gives the explanation of the ferrugination of these fossils. The younger Lipakou formation (middle Permian) is also composed of shales, but it is

probably too recent to contain such large species of *Imitoceras*.

From the above considerations, it is believed that these fossils came from the lower part of the Tzemenchiao limestone, which is Shangssuan or Viséan in age.

The writer wants first to express his thanks to those who have given their help in preparing this paper. He is much obliged to Prof. C. Y. Hsieh of the National Peking University, who kindly submitted these interesting specimens to the writer for study; to Prof. A. W. Grabau, who gave great encouragement. He is very glad to pay his deep gratitude to Prof. G. M. Kay of Columbia University, who gave encouragement and advice. He is much indebted to Prof. A. K. Miller of the State University of Iowa, who gave many valuable suggestions and carefully read over this paper.

The types of the specimens described in this paper are deposited in the Museum of the National Geological Survey of China.

DESCRIPTION OF SPECIES

Order NAUTILLOIDEA Zittel
Suborder ORTHOCHOANITES Hyatt
Family TRIGONOCERATIDAE Hyatt
Genus STROBOCERAS Hyatt

STROBOCERAS? sp.
Plate 9, figures 1, 2

Of this species, there is only one fragment. The shell seems to be rather evolute or discoidal in coiling, with a wide umbilicus. The whorl is quadratic in cross section, wider than high. The venter is broadly arcuate, with four longitudinal, distant, and moderately strong ridges of nearly equal magnitude. The venter is separated from the flanks by two sharp keels. The flank is smooth and turns inward. The sutures form a faint ventral lobe. The siphuncle is very small, orthochoanitic, and subcentral in position.

Occurrence.—Near Wushihchung, south of Changlingpu, Siangtan, Central Hunan. This specimen is the only representative of the genus found in the collection.

Family TRILOBOCERATIDAE Hyatt
Genus COLOCERAS Hyatt

COLOCERAS SINENSIS Chao, n. sp.
Plate 9, figures 3, 4

This species is represented by a single specimen. The shell is globose, small, with a diameter of 16.5 mm, and strongly involute. The umbilicus is very small or nearly closed. The whorl is low, broad, and semilunar in cross section, indented by the preceding whorl about one-half of its height. The venter is broad and regularly curved. The true shell has mostly been exfoliated, exposing the closely arranged septa. Traces of the shell, however, show that the surface is probably smooth or marked by lines of growth. The amount of increase in width in the last whorl is very rapid, thus the last whorl is 15 mm thick, though the preceding one is only about 7.5 mm thick; the living chamber is not preserved. The measured dimensions of the specimen are as follows:

MEASUREMENT OF COLOCERAS SINENSIS CHAO, N. SP.

	mm
Diameter (D)	16.5
Greater radius	9.0
Lesser radius	7.5
Height of last whorl (H)	8.0
Height of penultimate whorl	7.0
Height of last whorl above venter	6.0
Involution (I)	3.0
Thickness of last whorl (T)	15.0
Thickness of penultimate whorl	7.0
Width of umbilicus (U)	1.5
Shell ratios: U/D=0.09	
I/H =0.37	
T/H=1.87	
T/D=0.97	

The suture lines are closely arranged, with spaces ranging from 2 mm to 3 mm wide in the last whorl. The suture bends slightly backward on the venter, less than one millimeter.

Remarks.—This is the first species of the genus *Coloceras* ever found in China. It is quite like *Coloceras lirum* Girty[1] (1) in appearance, but is fairly well distinguished by its small size, its nearly closed umbilicus, and its closer septa. It differs from the *Coloceras sarvoensis* Kruglov, and *C. abichii* Kruglov from the Ural mountains[2] in the small umbilicus and low and broad whorl section. It is referred to this genus because of its globose shape, the strongly involute character of its whorls, and the nearly straight suture line across its venter.

[1] *U. S. Geol. Survey, Bull.* 544, pp. 237–238, 1915.

[2] *Acad. Sci. de l'Union des Rep. Soc.*, t. 3, pp. 3–206, 1928.

Occurrence.—Near Wushihchung, south of Changlingpu, Siantan, Central Hunan.

Family KONINCKIOCERATIDAE Hyatt
Genus STENOPOCERAS Hyatt
STENOPOCERAS? ORIENTALIS Chao, n. sp.
Plate 9, figures 5–7

The representative of this species is a single internal mold. The shell is comparatively large, moderately compressed laterally, and slightly involute, with an umbilicus about one-fifth of its greatest diameter. The whorl section is high, with a rather narrow and rounded venter, which is marked by three faint, low, spiral ridges; the maximum width is in the shoulder region. The flank of the whorl is flat, slightly swollen outward. The umbilicus is fairly well defined by the steep shoulder wall, which bends into the flank through a slightly rounded shoulder. The living chamber is partly preserved and is probably large. The surface sculpture of the shell is unknown. The siphuncle is very small, about 1 mm across, situated about one-third of the whorl section from the dorsum.

The external suture is composed of a high, broad, and angular ventral saddle and two low, very broad lateral lobes, with the ventral side steeply inclined backward. The lateral saddle is confined to the shoulder wall and is only observed in the latter half of the last whorl. The internal suture consists of a narrow tongue-shaped dorsal lobe.

Remarks.—This species is characterized by its highly pointed ventral saddle and the broad lateral lobes, the lateral shoulder saddle being confined to only the latter half of the last whorl. It is differentiated from *Stenopoceras dumbli* (Hyatt) because that species possesses a truncated venter in the premature stages, though it is more or less rounded in the adult stage, and has a larger umbilicus, which is about one-third of the width in *Stenopoceras dumbli*, about one-fifth in the present species. This species is related both to *Domatoceras* and *Stenopoceras*. The more strongly involute character of the whorl, the smaller umbilicus, and the presence of a lateral shoulder saddle lead the writer to assign it tentatively to *Stenopoceras*.

Occurrence.—Near Wushihchung, south of Changlingpu, Siantan, Central Hunan.

Order AMMONOIDEA Zittel
Family CHEILOCERATIDAE Frech
Genus IMITOCERAS Schindewolf
IMITOCERAS [AGANIDES] MULTISEPTATA Chao, n. sp.
Plate 9, figures 8–13

The shell is median in size, moderately compressed, strongly involute or nearly closed. The umbilicus is very small or absent. The whorl section is twice as high as wide and deeply indented by the preceding whorl. The venter is smooth and rounded, the flank being slightly compressed laterally. The shell has been worn away, so that the surface sculpture is unknown. The living chamber is very large, about two-thirds of the last whorl in length. In the type specimen (H104), it is strongly compressed and more or less crushed, so that a keel-like ridge is present on the venter. The following table shows the dimensions of the measured specimens:

MEASUREMENTS OF IMITOCERAS MULTISEPTATA CHAO, N. SP. (IN MM)

Collection and serial nos.	a H110	b H107	c H105	d H106	e H104	f H109
Diameter (D)	16.5	22.0	22.0	23.8	30.8	27.5
Greater radius	11.0	14.0	14.0	14.0	18.8	17.5
Lesser radius	5.5	8.0	8.0	9.8	12.0	10.0
Height of last whorl (H)	11.0	14.0	14.0	14.0	18.8	17.5
Height of penultimate whorl (h)	4.5	7.0	5.6	—	9.5	—
Height of last whorl above venter	7.5	7.0	8.6	—	12.3	—
Involution (I)	4.5	7.0	5.6	—	9.5	—
Thickness of last whorl (T)	9.5	12.0	12.0	14.5	—	17.5
Thickness of penultimate whorl	—	6.2	6.5	8.0	10.0	—
Width of umbilicus (U)	small	small	small	small	small	small
Shell ratios U/D	—	—	—	—	—	—
I/H	0.41	0.50	0.40	—	0.50	—
T/H	0.86	0.86	0.86	0.96	—	0.96
T/D	0.57	0.55	0.55	0.61	—	0.60

The external suture is quite like that of most species of this genus. It consists of a ventral lobe, a pair of lateral lobes, and two pairs of lateral saddles of unequal magnitude. The ventral lobe is long, narrow, and bottle-shaped. The lateral lobe is deep, sharp, and pointed backward. The first lateral saddle is high, narrow, rounded, and tongue-shaped; whereas the second is broad, with the dorsal side steeper. The end of the lateral lobe approaches the ventral side of the preceding lobe instead of pointing posteriorly to the middle. The internal suture is composed of corresponding but more crowded lobes and saddles.

Remarks.—The genus *Imitoceras* was erected by Schindewolf[3] in 1923, to include what have been called *Aganides* and *Brancoceras* by older authors. According to him, this genus ranges from Upper Devonian to middle Permian. More recently, Plummer and Scott have limited *Aganides* to large forms of Upper Devonian and Mississippian age. To the small forms of Pennsylvanian and Permian ages, they proposed a new genus *Neoganides*[4] taking *Neoganides grahamensis* Plummer and Scott as its genotype. This newly erected genus is characterized by its small size; undivided, narrow U-shaped ventral lobe; rounded lateral lobes directed toward the umbilicus; and two broad, rounded, nearly equal-sized saddles. The present species evidently belongs to *Imitoceras* [*Aganides*] instead of *Neoganides*. The median size, the more crowded septa in the inner whorl, and the less sharply pointed lateral lobe make it easy to distinguish from other Mississippian forms.

Occurrence.—The specimen type was found near Liangchiachiao, southwest of Changlingpu, Central Hunan. It is associated with *Hunanites hsiehi* Chao, n. sp.

Genus HUNANITES Chao, n. gen.
Genotype, *Hunanites hsiehi* Chao, n. gen., n. sp.

Conch ammoniticonic, subglobose or laterally compressed, strongly involute, with small umbilicus; whorl low, semicircular in cross section; venter regularly curved; surface marked by transverse ribs and grooves; suture line composed of 8 saddles and 8 lobes including the ventral lobe; ventral lobe long, slender, and serrated; first lateral saddle long, narrow, and spatulate in shape; second lateral saddle broad and short, with the ventral side more steep; first lateral lobe long and serrated by 3 to 5 indentations; second lateral lobe merges into the umbilical wall; internal sutures more crowded.

So far as our present knowledge goes, we have only two species in this new genus; both came from the same horizon (Shangssuan?) and two nearby localities, only about 1½ miles apart.

As to the phylogenetic relation of this genus, it seems to be closely related with *Imitoceras* [*Aganides*], which probably is its ancestral form; it differs in the serrate character of the lobes.

HUNANITES HSIEHI Chao, n. sp.
Plate 10, figures 1–9

The shell is moderate in size, subglobose in shape, and strongly involute, with a very small but fairly well defined umbilicus. The whorl is rather low, broad, and semicircular in cross section. The venter is regularly arched. The shell surface is marked by transverse ribs and grooves, which cross the venter and are gently sinuate posteriorly. They can easily be differentiated into three successive stages. In the nepionic stage there are single grooves at regular distances of about five mm. In the neanic stage, second grooves appear in front of the primary ones, enclosing ribs between them; these grooves with the intervening ribs occur at shorter intervals than in the nepionic stage and are separated by smooth areas; the character of this stage can be observed on the penultimate whorl of adult specimens. In the adult or ephebic stage, the separating smooth areas give way to regularly ribbed sculpture on the shell surface. The ribs usually become faint or disappear toward the umbilical shoulder. The primary ribs in the neanic and early ephebic stages are more prominent on the umbilical shoulder, then quickly die out toward the umbilical wall. The dimensions of some specimens are shown in the table:

[3] *Neues Jahrbuch, Beilageband,* 1923, 49, pp. 325.

[4] Texas Univ. Bull. 3701, 1937, pp. 349–350.

DIMENSIONS OF HUNANITES HSIEHI CHAO (IN MM)

Collection and serial nos.	a H112	b H113	c H119	d H120	e H121	f H122	g H123	h H124
Diameter (D)	16.00	28.20	13.50	16.80	28.00	29.00	28.00	26.00
Greater radius	9.00	15.40	8.50	10.00	16.50	17.00	18.00	15.00
Lesser Radius	7.00	12.80	5.50	6.80	11.50	12.00	10.00	11.00
Height of last whorl (H)	9.80	15.40	7.00	9.00	16.50	16.50	17.00	15.00
Height of penultimate whorl	—	8.70	—	—	8.50	8.00	9.00	8.00
Height of last whorl above venter	5.00	5.90	3.00	4.00	8.50	10.00	8.50	10.30
Involution (I)	4.00	9.50	4.00	5.00	8.00	8.50	7.50	7.60
Thickness of last whorl (T)	11.40	22.00	10.00	11.50	21.00	20.00	21.00	18.00
Thickness of penultimate whorl	—	15.00	—	—	10.40	12.20	14.20	14.00
Width of umbilicus (U)	0.50	1.50	0.70	1.00	1.30	—	—	1.50
Shell ratios U/D	0.05	0.05	0.05	0.06	0.05	—	—	0.05
I/H	0.44	0.62	0.57	0.56	0.55	0.51	0.44	0.51
T/H	1.27	1.43	1.43	1.28	1.27	1.21	1.24	1.20
T/D	0.71	0.78	0.74	0.68	0.75	0.69	0.75	0.69

The suture line is fairly well exhibited in most specimens without any special preparation. It consists of 8 saddles and 8 lobes including the ventral lobe. The external suture is characterized by 4 saddles and 5 lobes including the ventral lobe, which is long, slender, and serrate at the posterior end. There are 3 sharp, short serrations, with the middle one slightly longer. The first lateral saddle is high, narrow, and spatulate in shape. The second lateral saddle is rather low and broad, with the steep side on the ventral side. The first lateral lobe is long and narrow, with 4 or 5 sharp and short serrations like those on the ventral lobe, pointing posteriorly. The second lateral lobe meets the shoulder suture, forming a part of the umbilical lobe. The internal suture is more crowded.

This species is named in honor of Prof. C. Y. Hsieh of the National Peking University, Peiping, who first collected these interesting specimens.

Occurrence.—Type specimen (H122) was found near Liaochiachiao, southwest of Changlingpu, Siangtan, Central Hunan. Tzemenchiao limestone? Shangssuan, Fengnian system (Lower Carboniferous).

HUNANITES SIANGTANENSIS Chao, n. sp.
Plate 10, figures 10–16

The conch of this species is moderate in size, somewhat compressed laterally, strongly involute. The umbilicus is very small or nearly closed. The whorl section is comparatively high and narrow, with the venter regularly arched. More than one-half of the last whorl is indented by the preceding penultimate whorl. The shell surface is sculptured with regular, moderately strong ribs, which cross the venter continuously and are sinuate, about 3 mm. posteriorly. These ribs can be grouped into two categories: namely, the primaries, which become more prominent as short strong ridges or elongated nodes on the shoulder region, and the secondaries, which seldom reach the shoulder. They usually occur alternatively, though two secondaries lying between primaries are not uncommon. Sometimes they

---

EXPLANATION OF PLATE 9

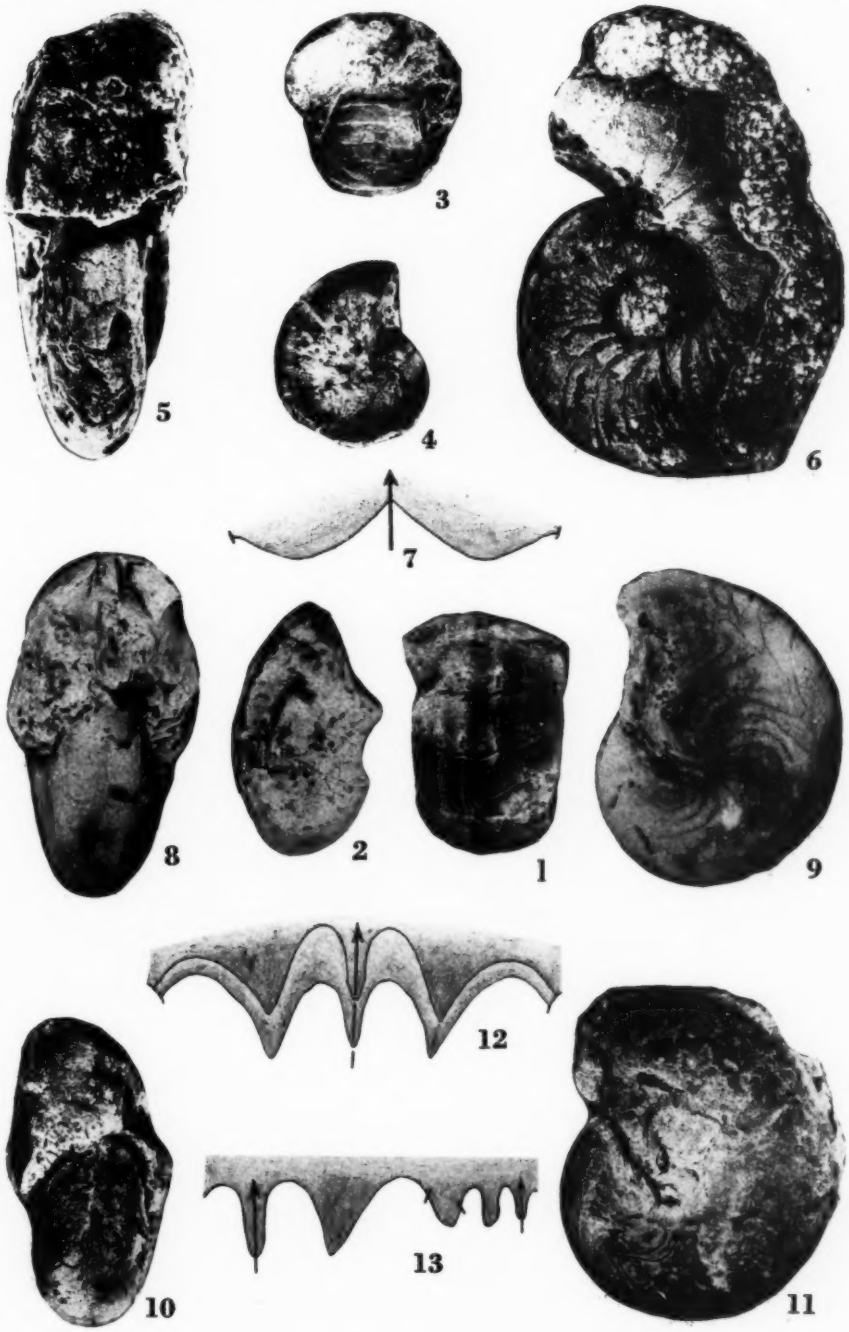
All specimens illustrated on this plate came from Tzemenchiao formation (?) of Shangssuan age (Fengnian or Lower Carboniferous) near Changlingpu, Siangtan, Central Hunan.

FIGS. *1, 2*—*Stroboceras* sp. Ventral and lateral views of a fragment showing the longitudinal ridges on the venter, ×2. (p. 69)

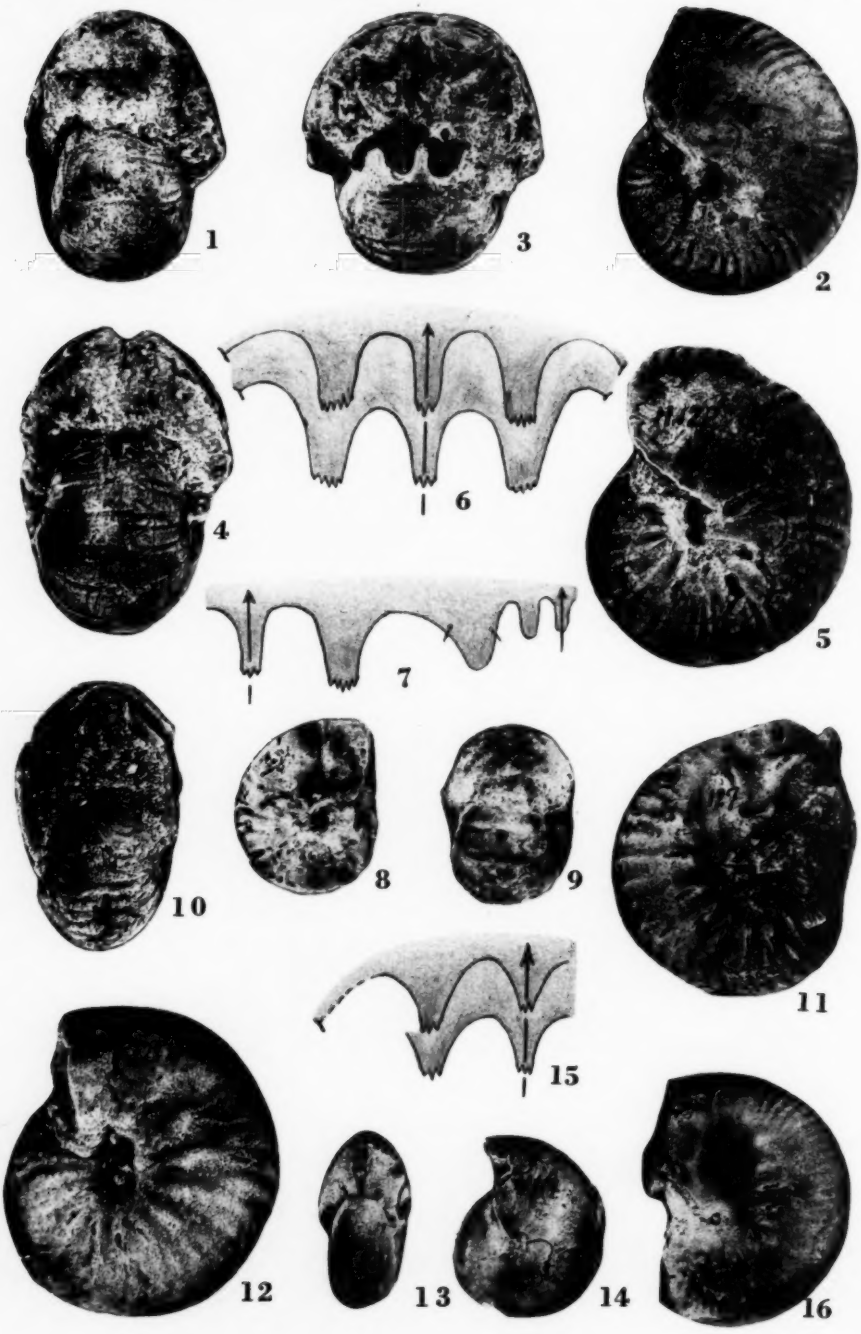
3, 4—*Coloceras sinensis* Chao, n. sp. Ventral and lateral views of holotype, ×1½. (p. 69)

5–7—*Stenopoceras orientalis* Chao, n. sp. *5, 6*, Ventral and lateral views of holotype, excess of limonite along the outer margin of the whorl, ×1½. *7*, Diagrammatic drawing of suture at the diameter of about 15 mm, slightly less than ×1½. (p. 70)

8–13—*Imitoceras multiseptata* Choa, n. sp. *8, 9*, Ventral and lateral views of paratype, ×2. *10, 11*, Ventral and lateral views of holotype, ×1½. *12*, Diagrammatic representation of external suture of holotype at diameter of 8 mm, ×2. *13*, Diagrammatic representation of suture line from different specimens, ×2. (p. 70)



Chao, Lower Carboniferous Cephalopods



Chao, Lower Carboniferous Cephalopods

DIMENSIONS OF HUNANITES SIANGTANENSIS CHAO, N. SP. (IN MM)

Collection and serial nos.		a H111	b H114	c H118	d H127
Diameter (D)		22.90	15.50	21.00	26.00
Greater radius		13.40	9.50	12.00	15.00
Lesser radius		9.50	6.00	9.00	11.00
Height of last whorl (H)		13.20	9.00	12.00	15.00
Height of penultimate whorl (h)		8.00	4.50	7.00	8.50
Height of last whorl above venter		7.00	4.50	6.50	10.00
Involution (I)		7.50	4.50	7.00	10.00
Thickness of last whorl (T)		12.00	8.00	10.00	14.60
Thickness of penultimate whorl		7.50	5.00	?	10.50
Width of umbilicus (U)		1.00	0.70	—	0.50
Shell ratios	U/D	small	small	small	small
	I/H	0.57	0.50	0.40	0.57
	T/H	0.91	0.89	0.83	0.97
	T/D	0.52	0.48	0.48	0.56

seem to be bifurcate. Below the flank and near the aperture of the last whorl, the shell is constricted, forming an irregular wavy region or a broad smooth depression as indicated by some specimens. In the type specimen (H127), the aperture is strongly constricted throughout and modified by a minor expansion, followed by another constriction, with a deep groove between. This implies that the animal has reached its gerontic age. There is also a narrow, deep sinus on the ventral side of the aperture.

In the young specimen (H114), which shows the same sort of suture and is referred to the same species, the shell surface is very smooth for the most part. This probably indicates that the shell surface in the young stage is smooth, not like that of the preceding species, *Hunanites hsiehi*. The surface becomes regularly ribbed in later stages, as indicated by some faint ribs near the aperture. The dimensions of four specimens are shown in the table.

The suture line is essentially like that of the preceding species, *Hunanites siangtanensis*. The external suture is characterized by a ventral lobe, four lateral saddles of different magnitude, and four lateral lobes. The ventral lobe is long, narrow, slender, and serrate, with three sharp indentations. The first lateral saddle is high, narrow, and tongue-shaped. The second lateral saddle is rather low and broad. The first lateral lobe is narrow, considerably tapering backward, and serrated by three to five indentations. The second lateral lobe forms a part of the umbilical lobe. The internal suture is more crowded.

Remarks.—This species can easily be distinguished from *Hunanites hsiehi* by the more laterally compressed nature of the shell, and the even, regular ribs throughout the outer volutions. Some specimens with rather fine ribs are also arbitrarily referred to this species, though they may form a variety, if not a third species of this genus.

Occurrence.—Near Liaochiachiao, southwest of Changlingpu, Fengnian system (Lower Carboniferous).

EXPLANATION OF PLATE 10

All specimens illustrated on this plate came from Tzemenchiao formation (?) of Shangssuan age (Fengnian or Lower Carboniferous) near Changlingpu, Siangtan, Central Hunan.

FIGS. *1–9—Hunanites hsiehi* Chao, n. gen., n. sp. *1, 2*, Ventral and lateral views of a paratype, ×1½. *3*, Ventral view of a paratype, ×1½. *4, 5*, Ventral and lateral views of holotype, ×1½. *6*, External suture line of holotype, slightly less than ×2. *7*, Diagrammatic representation of suture line from a paratype, slightly less than ×2. *8, 9*, Ventral and lateral views of a young specimen showing the nature of grooves in the young stage, ×1½. (p. 71)

10–16—Hunanites siangtanensis Chao, n. gen., n. sp. *10, 11*, Ventral and lateral views of holotype ×1½. *12*, Lateral view of a paratype, ×1½. *13, 14*, Ventral and lateral views of a young specimen showing the smooth character of the shell in the young stage and suture, ×1½. *15*, External suture line from a paratype (H. 131) at diameter of 9 mm, ×1½. *16*, Lateral view of a varietal form showing the finer ribs, ×1½. (p. 72)

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 74–77, PL. 11, JANUARY, 1940

LEBETOCRINUS, A NEW CRINOID GENUS FROM THE UPPER BORDEN OF INDIANA

EDWIN KIRK
Geological Survey, Washington, D. C.

ABSTRACT—A new crinoid genus, *Lebetocrinus*, based on a new species, *L. grandis*, from the upper part of the Borden group of Indiana is here described. The genus is related to the exceedingly rare *Bursacrinus* and is notable in having a plate arrangement in the posterior interradius hitherto unknown among crinoids.

IN THE Springer Collection in the U. S. National Museum were found several crinoids from the Borden group of Indiana that represent a new species and genus. As the crinoid is one of the largest inadunates hitherto found in the prolific crinoid fauna of either Crawfordsville or Indian Creek, it is astonishing that it has escaped observation and description. The genus is described chiefly on account of the anomalous nature of the posterior interradius, which is an unexpected variant from customary structures. At the present time inadunate crinoids that show unusual structural modifications are of great importance. Satisfactory criteria for the differentiation of genera and the establishment of genetic lines must be found before anything approaching a workable classification of this group will be possible. Specimens representing this new genus are very rare. A search was made for more material in the Peabody Museum at Yale University and in the Museum of Comparative Zoology at Cambridge without success. No specimens have been seen in the Walker Museum at the University of Chicago.

There is a plaster cast of a crinoid in the Springer Collection that probably pertains to the new genus. According to the label, in Mr. Springer's handwriting, the original specimen was in the Borden collection and had been collected by Harrod near Canton, Ind.

Genus LEBETOCRINUS Kirk, n. gen.

Genotype, *Lebetocrinus grandis*, n. sp.

Crown: Expanding gradually, then narrowing distad.

Dorsal cup: Broadly turbinate. Composed of relatively thin plates, with weak sutures.

IBB: Relatively large, showing clearly in side view.

BB: Large. With the exception of r post B, hexagonal in outline; r post B heptagonal, supporting anal x on its left upper shoulder; anal x also rests on the post B.

RR: Large. Articulating facets extend from 65 per cent the width of the radial to the full width as seen. In all cases the entire distal face of the R supports brachial structures, be they IAx or the overlapping lateral portions of the IIBr.

IBr: One axillary primibranch seems to be normal, though in one ray seen two are present. The IAx may extend the full width of the R, may reach but one lateral margin, or may be overlapped on both sides by the IIBr.

Arms: Long, stout, with rounded backs. The arms divide by dichotomy. As a rule, the rami remain simple above the third division. The majority of the IIBr and IIIBr are cuneate in outline. Distad the majority of brachials are quadrangular, or with but slightly sloping faces. The IIBr are closely crowded, being laterally appressed both within the ray and between adjacent rays, except as between the r and l post RR. The IIIBr are variable in number, ranging from 9 to 20.

Post IR: Anal x large, supported unequally by the post and r post BB, and extending above the level of the RR. X supports a large convex, median tube plate. This supports two tube plates on its upper, sloping shoulders. Each of these in turn supports a short series of tube plates that decrease in size distad.

Ventral sac: The ventral sac is not preserved in the one specimen where the arms are broken away. It is probable that the sac

was relatively short and composed of numerous small plates, supported by the posterior median series of heavy tube plates.

Column: The column is large, circular in outline, and has an unusually large lumen. The outline of the lumen cannot be determined with certainty as all the columns, because of the thinness of the walls, have been flattened.

Characteristic species of the genus.—*Lebetocrinus grandis* Kirk, n. sp. Upper part of Borden (Mississippian), Indian Creek, Montgomery County, Ind. Also probably at Crawfordsville and Canton, Ind.

Geologic and geographic distribution.—The genus is known only from the upper portion of the Borden group (lower Mississippian) of Indiana.

Relationships.—*Lebetocrinus* more nearly resembles the rare and little-known *Bursacrinus* than any other described genus. The general habit of the crown and the shape of the dorsal cup are similar. In *Bursacrinus* anal x is small and little more than reaches the post B. In *Lebetocrinus*, unique among described genera, anal x is very large and rests on the post and r post BB. The brachials in *Bursacrinus* are quadrangular in contrast with the cuneate brachials of *Lebetocrinus*. In *Lebetocrinus* the arms divide by dichotomy, whereas in *Bursacrinus* the arm divisions are heterotomous. The columnals in *Bursacrinus* are relatively higher and the lumen smaller than in *Lebetocrinus*.

Lebetocrinus may have directly derived from *Bursacrinus*. Both in turn may well have descended from a *Graphiocrinus*-like ancestor, though not from *Graphiocrinus* itself.

Remarks.—Sporadic variations from the norm are to be found in the number and arrangement of the anal plates in almost any genus of inadunate crinoid when a considerable series of specimens is available for study. A single anal plate instead of the normal three has been seen in several instances. Such cases can definitely be determined only by specific identification. Such an abnormal specimen found isolated, at a stratigraphic horizon without a known crinoid fauna or widely separated geographically from known crinoid faunas, either would be placed erroneously in the wrong genus or would be made the basis for a new genus. A number of specimens of the genus described in this paper show the unique structure. No crinoids are known in the prolific crinoid fauna of the horizon, which has yielded thousands of specimens, that agree in the other structural features shown by the new genus. Furthermore, in all individuals I have seen where a single anal is present as an abnormality it is centered on the posterior basal. These facts seem to prove that the peculiar structure of the posterior interradius is normal.

LEBETOCRINUS GRANDIS Kirk, n. sp.
Plate 11, figures 1–5

This species is represented by six splendidly preserved specimens. The two figured specimens lie on slabs of rock. One individual gives a posterior view and the other an anterior view. Of the four other specimens, two are completely freed from the matrix, and the other two show the posterior interradius. One specimen bore a label in Wachsmuth's writing "*Scaphiocrinus concinnus* Meek and Worthen." The other specimens were unlabelled and were distributed under various genera.

The species, for an inadunate, is a very large one. The crown of the largest individual has a height of 13.5 cm. Four of the crinoids are considerably smaller than the two specimens figured, but they agree in all essential characters with the types, and there is little doubt but that they are conspecific.

In all specimens the theca is crushed, the dorsal cup being made up of relatively thin plates and proving incompetent. The dorsal cup is broadly obconical, with a diameter, as nearly as can be judged, about twice the height. The surface of the plates is finely granulose. The infrabasals, five in number, form a prominent ring and have a height about four-fifths their width. They are about one-half the height of the basals. The basals are large and hexagonal in outline with the exception of the right posterior, which is heptagonal. The basals slightly exceed the radials in height. The radials are large, with a height about two-thirds their width. The articulating facet varies in width from about 65 per cent the width of the radial to the full width. This is a most unusual structure, and, although found elsewhere among the

crinoids, it is rare. This irregularity is caused not by variation in the width of the different radial series but by a diminution in the size of the first primibrach and its displacement on the upper face of the radial by overlapping and descending lateral portions of the first secundibrachs. Diagrams on the plate show two types of this structure, one in which the primaxil reaches the margin of the radial on one side and the other where the primaxil is completely enclosed by the radial and the two first secundibrachs. There is but one anal plate in the dorsal cup, which will be assumed to represent anal x. This plate is about the width of the radials but is higher. It rests below unequally on the posterior and right posterior basals, the contact with the right posterior basal being about one-half the length of that with the posterior basal. Above, the lateral margins of anal x are somewhat pinched in, arching the central portion of the plate. Anal x supports a single large tube plate, and its upper lateral margins are in contact with the adjacent first secundibrachs.

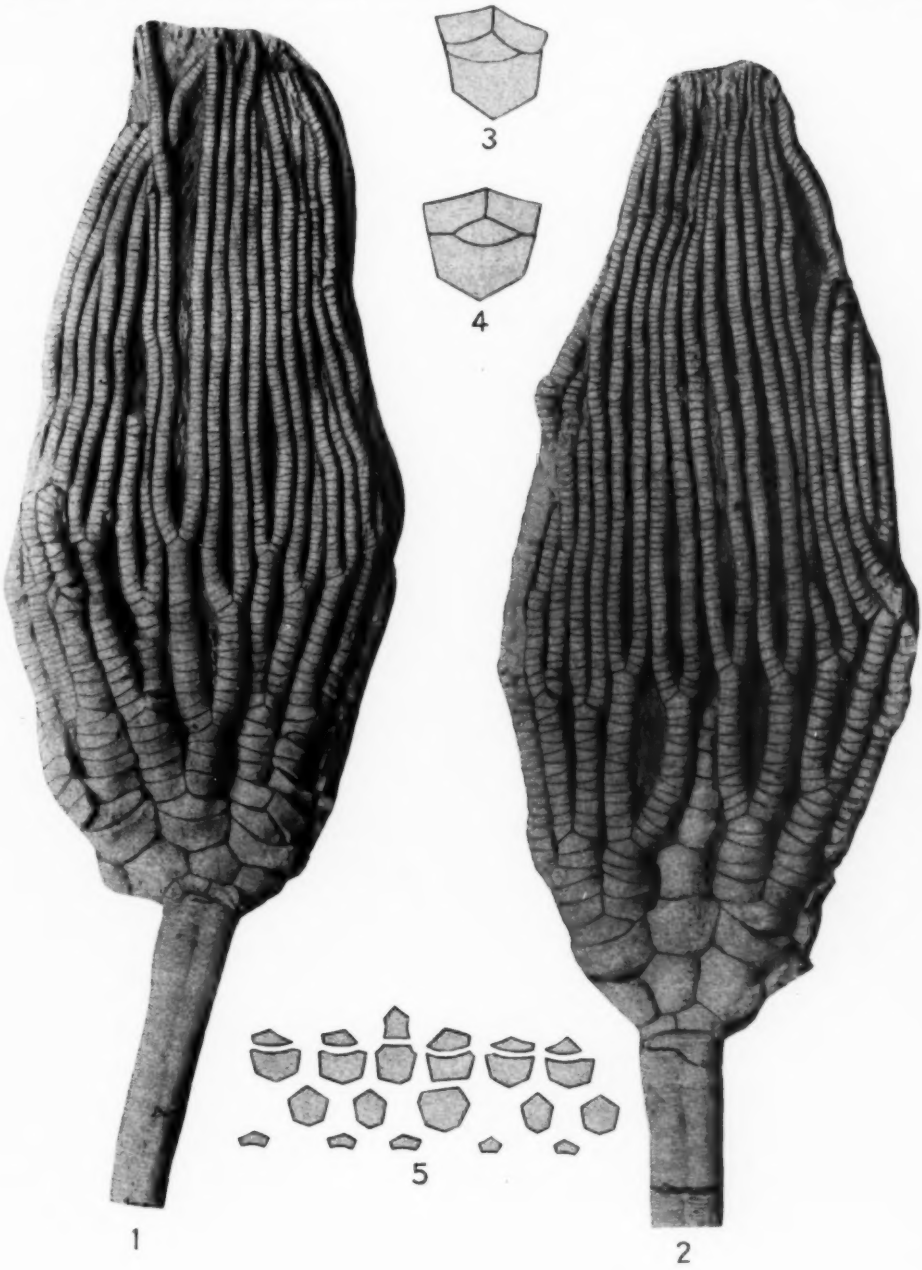
One primibrach, which is axillary, seems be be normal for the species. Out of 21 rays exposed, but one had two primibrachs. The primaxil is low and sits well down in the crescentic articulating facet. As noted above, the primaxil may extend the full width of the radial, may reach but one margin of the radial, or may be overlapped on both sides by the first secundibrachs. The secundibrachs are wide and heavy. They vary from nearly quadrangular in outline to distinctly cuneate. In a few instances one side of a secundibrach does not reach the margin of the ramus. The secundibrachs vary in number from 4 to 8. Out of 40 series counted, 15 had 6 brachials, 13 had 4, 10 had 5, and but 2 had 8. There seems to be little uniformity in the variation of the number of secundibrachs either within the ray or among the different rays. The secundibrachs are appressed laterally both within the ray and in adjacent rays, except in the right and left posterior rays, which are separated by anal x and a series of tube plates. The tertibrachs are as variable in number as the secundibrachs, ranging from 9 to 20, with all the intermediate numbers represented. Here again the number seems to be wholly fortuitous, not even being correlated with the number of secundibrachs in the same ray, which might be expected. As a rule, the rami remain simple above the third dichotomous division, but one exception being found. The brachials have well-rounded backs from their inception and distally become more and more rounded, finally becoming almost cylindrical. The majority of the IIBr and IIIBr tend to be cuneate in outline. Above the third bifurcation most of the brachials are quadrangular or with but slightly sloping faces. The pinnules are fairly stout and are borne, one to a brachial, by all the tertibrachs and succeeding brachials. Judging from the shape of the secundibrachs, pinnules may be borne by some of them as well, but owing to the close lateral crowding they have not been seen and may have become atrophied in adult individuals.

Anal x, as noted above, rests unequally on the posterior and right posterior basals, the contact with the posterior basal being almost twice the width of that with the right posterior basal. Anal x is slightly narrower but higher than the adjacent radials. The median portion of the upper face of anal x, to the extent of about 70 per cent the width of the plate, is arched and serves as a support for the first tube plate. On each side of the convex area the margins of the plate are pinched in, forming smoothly rounded concave shoulders. The first tube plate is very large, having a height about four-fifths that of anal x. It is very convex and supports two large tube plates on its upper sloping shoulders. One series of these secondary tube plates is shown to the number of five. The plates steadily diminish in size distad. Further than this the structure of the ventral sac is unknown. Judging by analogy, it is probable that the ventral sac was com-

EXPLANATION OF PLATE 11

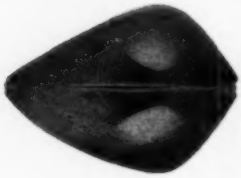
FIGS. *1–4*—*Lebetocrinus grandis* Kirk, n. sp. *1*, Anterior view; *2*, posterior view; syntypes, U.S.N.M., S4294, ×1. *3*, *4*, Details of brachial structures, showing first primibrach partially and wholly overlapped by the first secundibrachs; paratype, U.S.N.M., S4295. (p. 75)

5—Plate diagram of *Lebetocrinus* Kirk, n. gen. (p. 74)



Kirk, Mississippian Crinoid

1



2

3

4

5

Fritz, Devonian Ostracode
Usinger, Miocene Insect

posed of numerous small plates, with the exception of the posterior series of heavy tube plates that serve as a support for the otherwise incompetent structure.

The column is large, round, with an unusually wide lumen. In all specimens but one the column is flattened by crushing. In one specimen largely replaced by iron pyrites the proximal portion of the column is preserved. This is broadly oval in section, not having been completely flattened. The wall of the column has a thickness of but 1 mm, although the diameter of the uncrushed column at this point must have been at least 6.5 mm. The columnals alternate in height, the thicker averaging less than 1 mm and the thinner ones about one-half that. In a space of 1 cm in the proximal portion of the column, 20 columnals were counted. The columnals are firmly held together by deep closely interlocking crenulations.

Horizon and locality.—Of the six specimens, one was labelled by Wachsmuth as "Indian Creek, Montgomery Co., Ind." The two specimens figured are on slabs of rock of unmistakable Indian Creek lithology. Of the other three specimens, one is probably from Indian Creek, one is doubtful, and the other probably from Crawfordsville. This probable assignment to Crawfordsville is based on lithology of the matrix and a specimen of *Platycrinus hemisphericus* attached to the same piece of rock. The horizon is upper Borden.

Types.—The figured syntypes, the paratype, and the other three specimens used in drawing up the description of the species are in the Springer Collection in the U. S. National Museum. The syntypes are S4294, and the paratype from which the diagrams of the brachial structures are taken is S4295.

NOTE: Published by permission of the Director, Geological Survey, United States Department of the Interior. Manuscript received by the Editor June 9, 1939.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 77–78, PL. 12, JANUARY, 1940

APARCHITES CANADENSIS, A NEW DEVONIAN OSTRACODE FROM THE ONONDAGA OF ONTARIO

MADELEINE A. FRITZ
University of Toronto, Toronto, Canada

ABSTRACT—Up to the present time the genus *Aparchites* has not been recorded with certainty from the Devonian rocks of Canada. The new species *A. canadensis* described here is of particular significance in that it marks an important Devonian horizon in the oil wells of southwestern Ontario.

IN A PAPER (1) published during the past year the writer drew attention to several well-marked microfossil zones in the Upper and Middle Devonian strata that have been penetrated by drillers in the more important oil and gas fields of Kent and Lambton counties in southwestern Ontario. Of these zones two are characterized by the presence of ostracodes. The prolific fauna of the "upper ostracode" zone of the Hamilton formation has been described recently in some detail by Mary C. Turner (2). The present

EXPLANATION OF PLATE 12

FIGS. *1–3*—*Aparchites canadensis* Fritz, n. sp. Syntypes, Geological Survey of Canada, ×30. *1*, Right valve, no. 9406; *2*, hinge view, no. 9406; *3*, ventral view, no. 9407. (p. 78)
4, 5—*Procymus cockerelli* Usinger, n. gen., n. sp. Holotype, California Acad. Sci., paleontological type collection, no. 815. *4*, Corium of left hemelytron, ×67; *5*, entire insect, ×25. (p. 79)

paper deals with the most characteristic species of the "lower ostracode" zone that marks the lower part of the Onondaga formation. This zone was originally described as follows (3):

> This is one of the best-defined horizons studied. It is characterized by a new species of ostracode resembling the genus *Aparchites*. The form is sparingly developed but extraordinarily constant in its appearance throughout the lowest 60 feet of the Onondaga. Except in the Dawn, specimens of this ostracode have been identified from each of the fields under discussion. In the D'Clute field it is best represented, having been identified there in six of the eight wells studied.

Since the publication of the above statement the ostracode in question has been definitely recognized as belonging to the genus *Aparchites;* it has been given the name *Aparchites canadensis*.

Although the genus *Aparchites* ranges in time from the Ordovician to the Devonian (4) its occurrence in the Devonian is comparatively rare. Of the 43 species listed by Bassler and Kellet 16 belong to the Ordovician, 15 to the Silurian, five to the Ordovician and Silurian, and seven to the Devonian.

Of the seven species recorded from Canada only one *A. billingsi* (Jones) may be of Devonian age. The other six, *viz.*, *A. concinnus* (Jones), *A. minutissimus* Hall, *A. mundulus* Jones, *A. parvulus* Jones, *A. tyrelli* Jones, and *A. whiteavesi* Jones belong to the Ordovician.

In view of the foregoing remarks it is of considerable significance to find a typical species of *Aparchites* marking an important Devonian horizon in Ontario.

CLASSIFICATION AND DESCRIPTION

FAMILY LEPERDITELLIDAE Ulrich and Bassler

Genus, APARCHITES Jones, 1889

Jones' description of this genus follows:

> Shell not exceeding 3 mm in length, equivalved, subovate or oblong; hinge straight, ventral edge thickened, often bevelled or channelled; surface convex, mostly in the ventral half, smooth.

APARCHITES CANADENSIS Fritz, n. sp.

Plate 12, figures 1–3

The carapace is in general subquadrate in outline. The anteroventral portion of the valves is distinctly truncated and swings back boldly towards the centre of the ventral margin.

The hinge is straight and extends approximately three quarters of the distance across the shell. Towards the centre of the hinge there is a slight thickening of the shells. The cardinal angles are obtusely rounded, the anterior being slightly more acute.

The most obvious relief feature of the valves is a prominent swelling, which rises gradually from about the centre of each valve. It finally assumes rather an abrupt slope dorsally, where it terminates in an umbolike structure that protrudes slightly beyond the hinge.

There is a distinct bevelling in the valves. It begins near the cardinal angles but it is most noticeable at the thickened ventral margin. Here, at a distance of about 0.05 mm, it parallels the margin.

The surface of the valves shows exceedingly minute papillae, but these are so fine that the shells appear to be smooth.

The dimensions, which are strikingly constant in all the specimens examined, are: Length 1.1 mm, height 0.8 mm, thickness at centre 0.75 mm.

Remarks.—*Aparchites canadensis* resembles Jones' genotype, *A. whiteavesi* (5) more closely than any other species of which I am aware. It may be distinguished, however, by the smaller size (the genotype is 3 mm in length) the pronounced backward swing, the subquadrate form, and the well-developed umbonal gibbosity. The latter feature gives to the species the appearance of a small distinctly obese pelecypod.

Syntypes.—Geological Survey of Canada, Ottawa, nos. 9406 and 9407. Depth 480 feet in D'Clute well no. 14, Kent County, Ontario.

REFERENCES

1. FRITZ, MADELEINE A., *1939, Geol. Soc. America, Bull.*, vol. 50, no. 1, pp. 79–88.
2. TURNER, MARY C., *1939, Bull. Am. Paleontology*, vol. 25, no. 88.
3. FRITZ, MADELEINE A., *1939, op. cit.*, p. 87.
4. BASSLER, R. S., and KELLETT, BETTY, *1934, Geol. Soc. America, Special Paper* 1, p. 14.
5. JONES, T. RUPERT, *1889, Annals of Nat. History*, vol. 3, ser. 6, p. 384, text figs. 5, 6, pl. 17, fig. 10.

NOTE: Manuscript received by the Editor September 11, 1939.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 79–80, PL. 12, JANUARY, 1940

FOSSIL LYGAEIDAE (HEMIPTERA) FROM FLORISSANT

ROBERT L. USINGER
University of California, Davis, Calif.

DURING THE summer of 1937 a brief visit was made to the famous Florissant lake basin in Colorado. Aside from a general interest in whatever traces of insect life might be revealed by splitting up the fine Oligocene or Miocene shale, I was particularly anxious to collect representatives of Scudder's five "*Nysius*" species in connection with a monograph of the recent Orsillini in preparation. A considerable number of insects of various orders was collected including about two dozen Hemiptera (corixids, *Rhepocoris*, etc.), but the only undoubted lygaeid found proved to belong to the subfamily Cyminae. As I find no report of this subfamily in the records of fossil insects, the specimen, although unfortunately unique, is described below.

Later in the same summer, while visiting the Museum of Comparative Zoology, Scudder's *Nysius* types were examined. It was found that the arrangement of punctures on the clavus and corium of these fossils differs from that of any Orsillini known today. Dr. F. M. Carpenter very kindly loaned the material for further study. It is regretted that the report on this material is so incomplete, but many of the characters necessary in the classification of the Lygaeidae, even to subfamilies, e.g. the position of the abdominal spiracles and trichobothria and the fusion of certain abdominal segments, are not visible in these specimens. The most reliable means of preliminary placement of many fossil insects into families or genera is by general facies, but this breaks down entirely among the numerous tribes and genera of Rhyparachrominae. Hence, although it may some day be possible to place these more precisely, for the present at least it must suffice to say definitely where they do *not* belong. By this means errors by modern phylogenists as to the age of recent groups may be precluded.

I am greatly indebted to Dr. F. M. Carpenter for advice in connection with this paper and for the enlarged photograph showing details of the hemelytral punctures.

Genus PROCYMUS Usinger, n. gen.

Short, broad, and densely covered with typically cymine punctures. Corium densely punctate and with discal vein R+M very prominent, branched on apical half to form a large closed cell, as in the Australian genus *Cryptorhamphus* Stål. Apical margin of corium evenly rounded, as in typical *Cymus*. Costal margin greatly thickened, not at all expanded.

Genotype, *Procymus cockerelli* Usinger, n. sp.

PROCYMUS COCKERELLI Usinger, n. sp.
Plate 12, figures 4, 5

Head, including eyes, considerably broader than long, 25::17; a little narrower than pronotum, 25::30; interocular space beneath, a little less than three times as wide as an eye; eyes rounded posteriorly, attenuated anteriorly. Antennae about as long as width of head across the eyes; proportion of segments one to four as 4:7:6:7, the first segment stoutest, second and third linear, fourth fusiform. Under surface of head and thorax covered with dense round punctures. Ventral surface of abdomen impunctate, with a distinctly delimited short segment at base followed by a longer segment, beyond which the sutures are obscured. Male genital capsule evidently strongly exserted, rounded behind. Left hemelytron spread so that most of the corium but none of the clavus is exposed. Costal margin of corium very broad; straight or gently rounded at base, feebly sinuate before middle, and distinctly arcuate apically; almost twice as long as width of head.

Length 3.97 mm, width (head) 1 mm.

Holotype, male, the obverse, no. 815, California Academy of Sciences, Paleontological type collection, Florissant, Colorado, July 3, 1937, R. L. Usinger collector, and the reverse, unfortunately much less perfect but still showing the typical cymine punctures, which immediately place the species, in the Museum of Comparative Zoology.

It is with pleasure that I dedicate this species to Dr. and Mrs. T. D. A. Cockerell, who contributed so largely to the success of my visit to Boulder and Florissant.

Procymus is of exceptional interest because it exhibits a combination of primitive characters not found in our recent American Cyminae. The short, broad body form is not found in any other Cyminae known to me, and the prominent, branched corial vein is known to me only in the genus *Cryptorhamphus* from Australia, a region where one might expect to find primitive forms. That Cyminae of our modern type were present during approximately this same period in the earth's history is evidenced by the occurrence of *Cephalocoris* Heer at Oeningen. This genus was placed near *Lygaeus* by Heer, but it is obviously a perfectly typical member of the Cyminae and rather close to true *Cymus*.

A careful examination of 31 specimens of Scudder's type material representing his five species of *Nysius* reveals that none of these species actually belongs in *Nysius* or even in the subfamily Lygaeinae. Some Orsillini from Hawaii, St. Helena, and elsewhere, which we have reason to believe are primitive, have a row of distinct punctures on either side of the claval suture, but none of these has a row of punctures completely around the margins of the clavus. However, such an arrangement of punctures is typical of most other subfamilies of the Lygaeidae. As all of Scudder's species of "*Nysius*" possess these as well as other punctures along the veins or disk of the corium, it can be said with certainty that these species belong elsewhere. Type number 5065 (Scudder's 10969) is a perfectly distinct *Geocoris* seen in ventral view. It differs from Scudder's description of *infernorum* in its larger size, 4 mm, and complete hemelytra but should doubtless be placed here. Type numbers 5044 and 4397 (Scudder's numbers 14432 and 11549) are apparently not Hemiptera.

NOTE: Manuscript received by the Editor February 3, 1939.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 81–85, 6 TEXT FIGS., JANUARY, 1940

A TOOTHLESS BIRD FROM THE CRETACEOUS OF ALBERTA

R. M. STERNBERG
University of Toronto, Toronto, Canada

THE Steveville area of Alberta is world-famous for its fine dinosaur remains. For many years, however, collectors have wondered at the absence of evidence of birds in these extensive Cretaceous exposures. During the summer of 1936 a field party from the National Museum of Canada, under the direction of C. M. Sternberg, collected, in addition to several other fine specimens, one which is here described as avian. This specimen, which was discovered by the writer, was most generously turned over to him for preparation and study by Mr. Sternberg. To Mr. Sternberg, and to Dr. A. Wetmore who has been most generous with encouragement and advice, the author wishes to express his sincere appreciation.

Class AVES
Subclass NEORNITHES
Order CAENAGNATHIFORMES, new order
Family CAENAGNATHIDAE, new family
CAENAGNATHUS COLLINSI Sternberg, n. gen., n. sp.
Text figures 1–6

Type.—No. 8776, Geol. Survey Canada. The holotype is an admirably preserved lower jaw, complete except for the ventral border of the right ramus.

Horizon.—Pale beds of the Belly River series, Upper Cretaceous.

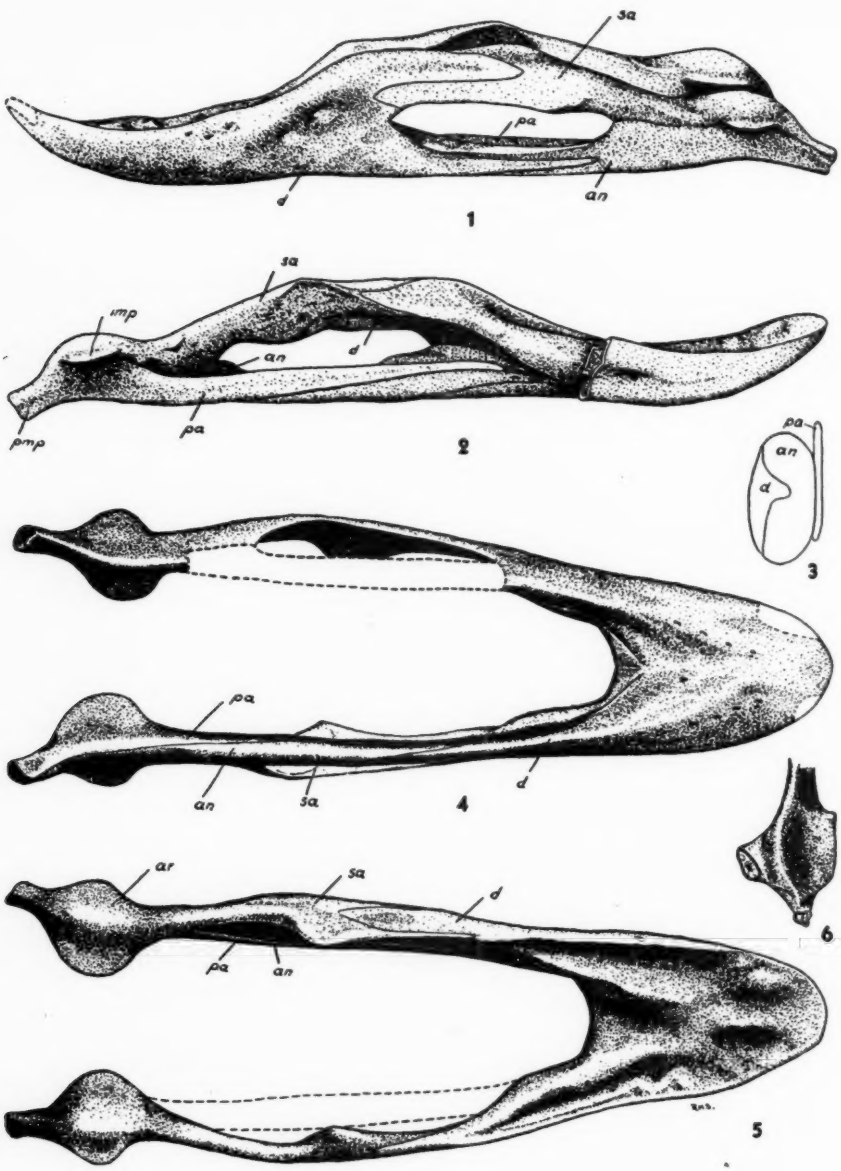
Location.—Quarry no. 112, Steveville map area, Alberta, Canada. This quarry is about 1½ miles due south of the mouth of Sand Creek, and about one-half mile east of the creek at this point. The elevation is 2184 feet above sea level, or 111 feet above the river.

Name.—The specific name is given in honor of the late Dr. W. H. Collins, for many years director of the Geological Survey of Canada.

Diagnosis.—No teeth; dentaries fused in symphysis; pars symphysis relatively long and broad; rami parallel; mandibular fossa large; articular surface large, oval and convex, with a ridged axis parallel to the direction of the ramus; mandibular processes short.

Mandibular fossa.—One of the most outstanding characteristics of this specimen is the large mandibular fossa. Starting from the anterior border, which is 105 mm from the tip of the mandible, this long fossa, with a somewhat flattened-oval shape, extends posteriorly 60 mm. Its greatest width is 14 mm, and it separates the dentary, angular, and surangular into upper and lower ramal branches. (Fig. 1.)

Dentary.—Just posterior to the pars symphysis, the dorsal border of the dentary rises steeply, so that above the mandibular fossa the ramus is nearly twice as high as at the pars symphysis. That part of the ramus dorsal to the mandibular fossa is formed by the dentary and surangular, the surangular forming the main body of the bone. Externally the dentary is in contact with the surangular as a wide, roundly tapered finger of thin bone, which extends posteriorly to above the middle of the mandibular fossa. This leaves the surangular showing as a Y-shaped bone, with one arm of the Y forming the most dorsal border of the ramus above the mandibular fossa, and the other arm forming the entire dorsoexternal border of the fossa. Internally the dorsal branch of the dentary is forked. (Fig. 2.) The anterior border of the mandibular fossa, both internally and externally, is formed by the dentary. The lower fork of the upper branch of the dentary, continuing from this anterior border, is both thin and narrow, but extends nearly to the middle of the fossa. The upper fork, which extends two-thirds this distance posteriorly, is wider than the lower fork, but is equally thin. This upper fork is medially offset 2 or 3 mm from the lower fork, showing the beginning of a ventrally facing groove, which extends forward and downward, paralleling the dorsal border of the dentary. Above the mandibular fossa the groove is roofed by an exposure of the surangular. Anteriorly, where the ramus widens



FIGS. *1–5*—*Caenagnathus collinsi* Sternberg, n. sp. Holotype, lower mandible, ×½, Geol. Survey of Canada no. 8776. *1*, Outer view; *2*, inner view; *3*, section through lower ramal branch 20 mm from anterior border of mandibular fossa; *4*, ventral view; *5*, dorsal view. *d*, Dentary; *an*, angular; *sa*, surangular; *pa*, prearticular; *ar*, articular; *pmp*, posterior mandibular process; *imp*, internal mandibular process.
6—Articular region of chicken, right side, ×2.

inwardly as it approaches the pars symphysis, the groove is wider and deeper. At the pars symphysis it becomes very narrow and shallow, and runs out onto the ventral surface, nearly joining its fellow to form a V. (Fig. 4.). The angular fits into this groove for a distance of 15 mm behind the pars symphysis.

The lower part of the ramus is formed by the dentary and angular. Though narrowing in width gradually, the thickness of the dentary is quite constant except near its end, under the posterior part of the mandibular fossa, where it thins, and the groove in the angular in which it fits becomes more shallow. Under the more anterior part of the fossa, the dentary and angular fit together in a tongue-and-groove arrangement as shown in figure 3.

The pars symphysis is relatively large for a bird; it is more than one-quarter the total length of the mandible and more than half as wide as long. Ventrally the posterior part of the pars symphysis is flat, though ridged slightly on each side where the rami enter it. The sides are sharply upturned, the front more gradually, giving one the impression of the bottom of a deep spoon. The surface is smooth except for several small foramina. These are parallel, and they follow the direction of each ramus. (Fig. 4.)

The superior surface of the pars symphysis is quite rugose. Continuing down from the highest part of the dentary, a sharp ridge borders this entire area. Internally, 10 mm or so below this highest point, a broadly rounded ridge goes forward, inward, and then parallel to the peripheral ridge. The internal ridges run together near the centre of the pars symphysis, forming a single ridge, which in a very short distance smoothes to the spoon-shaped anterior end. Between this inner ridge and the peripheral ridges on each side are moderately deep grooves, averaging 7 mm in width. The grooves are narrower and deeper posteriorly. Directly opposite the middle of the pars symphysis a nipplelike protuberance stands out from each peripheral ridge into the lateral grooves; 10 mm behind these on each side is a similar bump. In front, what may have been similar structures have been smoothed off to low rounded ridges, which point posterointernally. Between these protuberances and on each side of the anterior median ridge, are semicircular pits. In addition to these, there is a large smooth depression in the posterior part of the pars symphysis between the two internal ridges. The lateral depressions might suggest alveolar pits.[1] Their irregularity in size, shallowness, and smoothness, however, suggest that, if alveolar, these pits are purely vestigial.

Angular.—The angular is a moderately strong bone, extending from the pars symphysis to the tip of the posterior mandibular process. Throughout most of its length it takes part in the ventral border of the ramus. From its medial position anteriorly the angular twists in such a manner that its posterior third is lateral. Anteriorly the angular tapers to a point and is paper-thin, fitting into a groove on the inner part of the dentary as described above. At the anterior end of the mandibular fossa it has thickened considerably and has attained a height of 2 mm. Continuing posteriorly as the ventral border of the fossa, the angular tends to embrace the dentary. This relation may be seen in figure 3. At first high and ridged, the angular flattens posteriorly, forming the fairly thick and flat ventral margin of the mandibular fossa. This is shown, though not distinctly, in figure 1. Near the posterior margin of the fossa the bone is again ridged, and it appears to be folded down on each side of the surangular. Its posterointernal limits can not be definitely determined, but it may extend back to the deep notch just in front of the internal mandibular process. (Fig. 2.) Externally the angular continues to the extremity of the mandible; the upper margin is thin, the lower much heavier. The entire angular has been pulled off the right ramus, and a roughened area on the side of the surangular rather sharply delimits the former union of these two bones.

Surangular.—The surangular is a strong, well-defined bone, articulating with the dentary, angular, and prearticular, and fusing posteriorly with the articular. That part of the surangular bordering the top of the mandibular fossa is very sharp and knifelike

[1] X-ray pictures of the symphysial region, very kindly taken for the author by Dr. James Coupland of Ottawa, show no indication of tooth germs.

for more than half the length of the fossa. Then it thickens, and is gently rounded where it forms the posterior border of the fossa. The coronoid process, slightly posterior to the centre of the jaw, is a low, broad-based projection, roughened at the tip and smoothly continuous with the rest of the bone. Below this, on the inside of the bone, is a roughened oval surface inclined backward at an angle of 60° to the horizontal. The posteroventral margin of this oval is separated from the rest of the bone by a small groove, which may be seen just above *an* in figure 2. Behind the mandibular fossa, the surangular (plus the fused articular) forms the main body of the ramus, although it is overlain both inside and outside by the angular and prearticular. Outwardly the angular rises more than half the height of the ramus. Inwardly the surangular appears to cut forward into the angular, and its anterior limits can not be determined.

Articular.—The articular region is not at all reptilelike, but approximates the condition found in several birds rather closely. For example, a comparison of the articular region of a chicken (fig. 6) with that of *Caenagnathus* (fig. 5) shows that in each there is a subcircular expansion ridged more or less medially by a continuation of the dorsal border of the ramus. In the chicken the ridge is sharper and relatively not so high, is more medial and lies at a slight angle to the ramal direction. In *Caenagnathus* it is relatively a little wider, higher, and rounder, and is laterally displaced on the area. In both species the ridge is a direct continuation of the slender dorsal border of the ramus. The areas on either side of the ridge appear more concave in the chicken and goose, but this is mostly due to a greater and upward development of the internal and external mandibular processes. In *Caenagnathus* these processes are of equal size and are fairly stout, subcircular and horizontal. It might be noted here that the mandibular processes of birds seem to vary through all degrees of size and disposition. The posterior mandibular process is fairly short and extends downward; this downward extension, though uncommon, is not unknown amongst birds.

Prearticular.—The bone here called prearticular is a long, thin bone extending from the end of the posterior mandibular process forward nearly to the symphysis. (Fig. 2.) Anteriorly it is very thin and narrow and is closely applied to the medial surface of the angular. Posteriorly it becomes gradually wider. In the articular region, where it overlies the surangular and angular medially, the prearticular covers the base of the internal mandibular process completely and seems to continue backwards to sheet the inside of the posterior mandibular process. From near its first contact with the surangular, just back of the posterior border of the mandibular fossa, the prearticular thickens ventrally and forms half or more of the ventral surface of the ramus. (Fig. 4.)

Discussion.—The uniqueness of this specimen makes it extremely interesting, and any taxonomic position assigned it will no doubt give rise to considerable discussion. Taxonomy at its best is fairly arbitrary; characters are not always given the same value by different authors. Anticipation and discussion of objections to the assignment of *Caenagnathus* to the class Aves should lead to a clearer understanding of the problem. Dr. A. Wetmore, in a letter to the writer has pointed out several relevant facts, some of which have been incorporated in the following observations.

The anterior fusion of the dentaries into a perfectly smooth symphysis is certainly an avian character. True, a like fusion is found in Chelonia and Dicynodontia. In both these cases, however, there is a tendency toward the fusion of many other bones. Also, it is interesting to note that in certain Chelonia, such as the Chelydridae, a symphysial suture has been observed in young individuals. Every other bone contact in *Caenagnathus*, with the exception of the fused articular-surangular contact, is extremely free, or even partly disarticulated. In modern birds, though there is a certain amount of fusion of the elements of the lower jaw, the outlines of many can be seen quite easily. This might suggest, then, that the fusion of the dentaries in *Caenagnathus* is not part of a general fusion of all elements, as in some reptiles, but is of the avian type. The presence of the unfused symphyses in *Hesperornis* and *Ichthyornis*,

like the presence of teeth in these forms, indicates only that they are more primitive than *Caenagnathus*.

Absence of teeth is a prominent avian character, although a character not confined to birds. All Cretaceous birds hitherto known from skulls or jaws possess well-developed teeth, and although Lambrecht (1) lists several birds of modern aspect from the Cretaceous of Europe, our outstanding paleornithologists have always considered toothless birds in America to be confined to post-Cretaceous times (2). Hence the occurrence of a toothless bird in the Cretaceous of Alberta is unexpected but not necessarily impossible. In an article titled "Fossil Birds" (3), Dr. Wetmore writes.

> It is reasonable to expect that running forms and forms specialized for life among trees existed in that (Cretaceous) period in addition to the two types known, as birds have regularly adapted themselves to such environments.

It is reasonable to expect also that some of these forms would be toothless. From the size of the mandible, *Caenagnathus* might well be an example of a running type.

The articular region has been discussed above, and little can be added here. The presence of the internal, external and posterior mandibular processes is, of course, definitely an avian character. These, together with the ridged articular surface and the fused dentaries, make the fundamental similarity of plan between *Caenagnathus* and the avian mandible very evident.

Megascopic bone structure gives more or less unreliable evidence as to taxonomic position. The mandibular bones of *Caenagnathus* that are not merely thin sheets are quite cancellous. This type of structure, common to all birds, is found also in some dinosaurs. Microscopic investigation of the structure in comparison with other birds and reptiles is being carried on, but as yet promises little.

From the above discussion it seems that *Caenagnathus* must be a bird. The writer also feels, with apologies to those who must learn and teach paleontological taxonomy, that the characters necessitate the erection of a new order, Caenagnathiformes, and a new family, Caenagnathidae. The ordinal and family characters would be provisionally those which conform with the generic diagnosis.

As regards a life picture of *Caenagnathus*, one can of course do little more than speculate. Its large size would suggest a runner, and an upland habitat, such as has been postulated for *Troödon*, might account for its rareness in the Belly River series.

REFERENCES

(1) LAMBRECHT, K., *1933, Handbuch der Palaeornithologie*. Berlin.

(2) WETMORE, A., *1930*, The age of the suppoed-Cretaceous birds from New Jersey. *Auk*, vol. 47, p. 188.

(3) ——, *1933, Fossil birds; fifty years progress of American ornithology*, p. 239.

(4) LEBEDINSKY, N. G., *1919*, Beiträge zur Morphologie und Entwicklungsgeschichte des Unterkiefers der Vögel: *Naturf. Gesell. Basel, Verhandl.*, Band 31, pp. 39–112, 195 figs.

(5) ——, *1921*, Der Unterkiefer der Vögel: *Univ. Latvia, Acta*, Band 1, pp. 1–33.

JOURNAL OF PALEONTOLOGY, VOL. 14, NO. 1, PP. 86–88, JANUARY, 1940

"LUCITE" AS AN AID IN STUDYING HARD PARTS OF LIVING AND FOSSIL ANIMALS

ROBERT R. SHROCK
Massachusetts Institute of Technology, Cambridge, Mass.

ABSTRACT—Recently developed transparent plastics deserve consideration for use in studying the hard parts of living and fossil organisms. Possible uses include: (1) construction of artificial molds, casts, replicas, etc.; (2) as a matrix for embedding specimens that are to be studied in polished or thin section, or by serial sectioning; and (3) as a mounting medium for exhibiting or permanently preserving specimens. "Lucite," a tough, transparent resin recently developed by E. I. du Pont de Nemours and Co. is described and a few helpful hints for its use are given.

"LUCITE" is a fairly hard, tough, crystal-clear resin composed of polymerized methyl methacrylate. Its properties are described in a pamphlet (du Pont, 1936) issued by the manufacturers, E. I. du Pont de Nemours and Co., Plastics Department, 350 Fifth Avenue, New York, N. Y., and further information about its properties and uses are gixen in the articles listed in the bibliography. The plastic is soft enough to be carved with a sharp knife blade, yet sufficiently hard and tough to furnish an excellent bond for friable materials that are to be studied in thin section. The finely frosted surface resulting from grinding may be rendered transparent by polishing on a velveteen lap with liquid soap. The plastic is soluble in numerous organic solvents but very resistant to most common acids. Finally, it can be obtained from the manufacturers as an unpolymerized monomeric liquid.[1]

Possessing these desirable properties, "Lucite" is excellently suited for numerous uses in studying the hard parts of living and fossil organisms and as a matrix for consolidating fragmental or detrital materials containing microscopic fossils. Only uses in connection with the study of animal hard parts are considered here, but there are also numerous ways in which the plastic may be employed in studying animal soft parts and plants.

[1] The methyl methacrylate monomer may be purchased from the Ammonia Department, E. I. du Pont de Nemours and Company, Wilmington, Delaware at an approximate cost of $7.00 per gallon (their smallest commercial shipment is one gallon).

PREPARATION OF METHACRYLATE FOR USE

The plastic comes from the manufacturers as monomeric methyl methacrylate—a freely flowing, colorless and volatile liquid, the fumes from which are toxic and inflammable. All necessary precautions, therefore, should be taken in handling it. This monomer may be solidified (polymerized) by several simple operations that are described in the pamphlet furnished by the manufacturers and in a recent article by Bell (1939). When the monomer is ready for use it should be a colorless fluid with about the consistency of table syrup.

USE IN MAKING MOLDS, CASTS, REPLICAS, AND IMPRESSIONS

Hollow structures, such as shells, and solid parts of invertebrate and vertebrate animals may be fossilized in a variety of ways, depending in part on the mode and conditions of death and burial and in part on subsequent modifications. Some of these modes of fossilization can be demonstrated readily and clearly by mounting hard parts in a medium of "Lucite (see Bell (1939) for" a discussion of mounting technique).

Hollow shells like those of pelecypods, gastropods and cephalopods (*Nautilus*) may be embedded in the plastic and then subsequently removed by solution with dilute hydrochloric acid. This is accomplished by boring a small hole through the plastic to the surface of the shell and then immersing the entire mount in acid and allowing it to remain until all of the shell matter has dissolved. The resulting cavity is an artificial

mold, consisting of an external impression (external mold) and a core or filling (also called an internal moid) on the surface of which is an internal impression. An artificial cast of the original shell may be obtained by filling the mold with plaster of Paris or some similar material. Before the shell is mounted, it should be perforated with several small holes to insure that the monomer completely fill the hollow interior. The rods of "Lucite" formed in the perforations will hold the core in place when the shell matter is dissolved away.

It is possible to produce a replica of a hollow shell in the following manner. First, completely fill the hollow part of the shell with finely ground limestone, or some similar soluble material; then embed it in the plastic. Shell and filling may then be removed by dissolving with dilute hydrochloric acid. The resulting cavity, an external mold, will, when filled with plaster of Paris or some similar substance, produce an artificial replica of the original shell.

Solid hard parts, such as echinoid spines, may be duplicated in the same manner as just described for filled shells. The artificial filling in this case, however, is a cast rather than a replica, since the original object was solid rather than hollow.

Other modes of fossilization can be demonstrated once one appreciates the potentialities of the plastic and has gained some experience in handling it successfully.

USE AS MOUNTING MEDIUM FOR SECTIONS

"Lucite" makes a strong, firm bond for mounting loose microfossils and friable fossiliferous rock. It serves equally well for mounting larger specimens that are to be studied by polished or thin section or by serial sectioning. The plastic is sufficiently hard and tough that it can be ground readily with common carborundum powders to any desired shape, and the frosted surface resulting from grinding may be polished and rendered transparent once the desired shape has been attained. It also grasps mounted specimens firmly and adheres tenaciously to glass with a balsam cement. As the plastic has a high degree of transparency, it is possible to orient a desired section quickly and to saw the block in any selected direction.

Polished sections.—Hard parts of living and fossil animals may often be studied with profit in polished sections. To make such sections the specimen is mounted in the monomeric methacrylate and, after the latter has hardened, mounting and specimen are then sectioned in the desired direction. The sectioning may be done with an ordinary hacksaw or with a thin carborundum saw. It is not advisable to cut "Lucite" with a diamond saw. Once the desired surface has been prepared, it can then be polished and made ready for study. If desired, the entire block may be sized and shaped before study or storage.

Thin sections.—After the specimen has been mounted and the desired sections have been cut, the thin slices composed of specimen and grasping plastic are first polished, then mounted on ordinary microscopic slides with canada balsam, and finally ground down to desired thickness. The slight heat necessary to keep the balsam fluid in mounting the thin slices and putting on the cover glasses does not affect the plastic.

Serial sectioning.—Serial sectioning may be facilitated by using "Lucite" as the mounting medium. The block containing the specimen can be ground or machined to any desired shape before sectioning begins. "Lucite" might also be used instead of plaster of paris in a technique recently described by Zdansky (1938, 385–386).

USE AS TRANSPARENT MOUNTING MEDIUM

"Lucite" is an ideal medium for mounting all kinds of specimens for exhibition or for permanent preservation. It is especially superior because of its high degree of transparency and because of the ease with which the mounting can be shaped by grinding or machining (Lockrey, 1937), making it possible thereby to obtain the desired orientation of the mounted specimen. An additional desirable feature is that objects embedded in cylindrical or spherical mounts appear somewhat magnified when viewed through the curved surface.

BIBLIOGRAPHY

BELL, J. F., *1939*, Notes on the uses of methyl methacrylate "Lucite" in a geological laboratory: *Econ. Geol.* (In press.)

COLE, E. C., *1938*, Methyl methacrylate as a

laboratory tool: *Science*, vol. 87, pp. 396–398.
DU PONT DE NEMOURS, E. I., AND CO., *1936*, Methacrylate resins: *Ind. and Eng. Chemistry*, vol. 28, pp. 1160–1163.
FENT, L. S., *1939*, "Lucite" for microscopic transillumination: *Science*, vol. 89, pp. 371–372.
HIBBEN, J. H., *1937*, The preservation of biological specimens by means of transparent plastics: *Science*, vol. 86, pp. 247–248.
KNIGHT, H. G., *1937*, The preservation of biological specimens by means of transparent plastics: *Science*, vol. 86, pp. 333–334.
LOCKREY, A. J., *1937*, *Plastics in the school and home workshop*. Governor Pub. Corp., New York City.
RICHARDS, O. W. and SMITH, J. A., *1938*, Lucite not a substitute for canada balsam when mounting microscope slides: *Science*, vol. 87, p. 374.
SKILES, B. F. and GEORGI, C. E., *1937*, The use of synthetic resins in the preparation of permanent bacterial mounts: *Science*, vol. 85, pp. 367–368.
ZDANSKY, O., *1938*, An improved apparatus for the serial sectioning of fossils: *Science*, vol. 88, pp. 385–386.

SOCIETY RECORDS AND ACTIVITIES

ILLUSTRATED CARD CATALOGUE OF NORTH AMERICAN DEVONIAN INVERTEBRATES

The fourth and fifth units of the illustrated catalogue of North American Devonian fossils, prepared by Dr. Rudolph Ruedemann under the direction of a committee of the Paleontological Society, E. M. Kindle, chairman, is now ready for subscribers. Orders for either or both sets should be sent to Wagner Free Institute of Science, Montgomery Avenue and 17th Street, Philadelphia, Pa.

The fourth unit, comprising 16 sheets, includes the original figures and descriptions (only two abbreviated) of all known North American Devonian Meristomata, including the Euripterida and the Ziphosura. The paragraphs on occurrence include much new and important information concerning the several species. The price is $0.80, plus cost of packing and postage.

The fifth unit, the graptolites, comprises 13 cards. The price is $0.60, plus cost of packing and postage.

SEPARATE PLATES FOR SALE

Separate copies of plates from this JOURNAL subsequent to Volume 4, Number 2 may be purchased, if in stock, from the Society of Economic Paleontologists and Mineralogists, Box 979, Tulsa Okla., at the following prices: For orders of 1 to 10 plates, 10 cents per plate, postage prepaid; additional plates on same order, 2 cents each; a set of 291 miscellaneous, nonconsecutive plates, $6.62.

An A.A.P.G. Book (1939)

RECENT MARINE SEDIMENTS

A SYMPOSIUM OF 34 PAPERS BY 31 AUTHORS

EDITED BY

PARKER D. TRASK

U. S. GEOLOGICAL SURVEY, WASHINGTON, D.C.

PREPARED UNDER THE DIRECTION OF A SUBCOMMITTEE OF THE COMMITTEE ON SEDIMENTATION OF THE DIVISION OF GEOLOGY AND GEOGRAPHY OF THE NATIONAL RESEARCH COUNCIL, WASHINGTON, D.C.

CARL W. CORRENS, STINA GRIPENBERG, W. C. KRUMBEIN, PH. H. KUENEN, OTTO PRATJE, ROGER REVELLE, F. P. SHEPARD, H. C. STETSON, PARKER D. TRASK, CHAIRMAN

MEMBERS OF COMMITTEE ON SEDIMENTATION

ELIOT BLACKWELDER, M. N. BRAMLETTE, CARL B. BROWN, M. I. GOLDMAN, M. M. LEIGHTON, H. B. MILNER, F. J. PETTIJOHN, R. DANA RUSSELL, F. P. SHEPARD, H. C. STETSON, W. A. TARR, A. C. TESTER, A. C. TROWBRIDGE, W. H. TWENHOFEL, T. WAYLAND VAUGHAN, C. K. WENTWORTH, PARKER D. TRASK, CHAIRMAN

This book is on the topic of Sedimentation and Environment of Deposition recently voted No. 1 in geological research of most importance to the progress of petroleum geology,—in a poll of the 3,000 A.A.P.G. members and associates, conducted by the Research Committee. Throughout the book, the basic data—observational facts—are emphasized rather than speculative inferences.

- **736 pages; 139 figures**
- **Bibliographies of 1,000 titles; 72 pages of author, citation, and subject index**
- **Bound in blue cloth; gold stamped; paper jacket; 6x9 inches**

PRICE: $5.00, POSTPAID

($4.00 TO A.A.P.G. MEMBERS AND ASSOCIATE MEMBERS, LIBRARIES, AND COLLEGES)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

BOX 979, TULSA, OKLAHOMA, U.S.A.

London: Thomas Murby & Co., 1, Fleet Lane, E.C. 4

Verlag von Gebrüder Borntraeger in Berlin W 35 Deutschland

Fortschritte der Paläontologie. prepared under direction of O. H. Schindewolf, Berlin, with aid of numerous specialists. Vol. 1—Review of the years 1935-1936, contains 384 pp., 2 figs. Price, RM 29.60.

Fortschritte der Paläontologie is intended to be a biennial publication indicating significant advances in paleozoology and paleobotany by means of critical summaries and discussion of the most important works issued in successive two-year periods. The first volume, now available, covers literature of 1935 and 1936, and provides a comprehensive view of the present status of paleontological research.

Paläontologie, Entwicklungs- und Vererbungslehre (Paleontology, Evolutionism and Genetics) by O. H. Schindewolf; contains 108 pages, 34 text figures; published 1936. Price, RM 5.20.

This volume develops from paleontological observations and theoretical considerations a new orientation of studies on evolution. Critical inquiry on questions of evolutionary factors and a refutation of Lamarckian theories leads to accommodation of previously divergent views on evolution and heredity.

Detailed descriptions and prospectuses free

BACK VOLUMES AT HALF PRICE

Members and associate members of the Society of Economic Paleontologists and Mineralogists and of the Paleontological Society and subscribers of the

JOURNAL OF PALEONTOLOGY

will be privileged for a limited time to purchase complete Volumes 2 (1928) to 11 (1937) at the very special price of Three Dollars ($3.00) per volume. This offer represents a 50 per cent discount from regular prices and gives opportunity that should not be overlooked. Furthermore, only part of the supply of back volumes will be sold at this price. The stock of Volume 1 is exhausted, but any others can be purchased. Place order promptly if you wish to secure discount because this offer will be withdrawn as soon as allotment of copies is exhausted.

Members and associate members of the Society of Economic Paleontologists and Mineralogists and subscribers of the

JOURNAL OF SEDIMENTARY PETROLOGY

may purchase, for a limited time, complete Volumes 1 (1931) to 7 (1937), at half price, One Dollar and a Half ($1.50) per volume.

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
Box 979, Tulsa, Oklahoma

OFFICERS OF THE SOCIETIES

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

For the year ending April, 1940

President, GAYLE SCOTT, Fort Worth, Texas.

Past-President, E. H. SELLARDS, Austin, Texas.

Past-President, S. G. WISSLER, Compton, Calif.

Vice-President, HERSCHEL L. DRIVER, Glendale, Calif.

Secretary-Treasurer, HENRYK B. STENZEL, Austin, Texas.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

For the year ending April, 1940

President, HENRY A. LEY, San Antonio, Texas.

Past-President, DONALD C. BARTON, Houston, Texas.

Vice-President, L. MURRAY NEUMANN, Tulsa, Okla.

Secretary-Treasurer, ED. W. OWEN, San Antonio, Texas.

Editor, W. A. VER WIEBE, Wichita, Kansas.

Society Headquarters, 608 Wright Bldg., Tulsa, Okla.

PALEONTOLOGICAL SOCIETY

For the year ending December, 1939

President, C. O. DUNBAR, New Haven, Conn.

Past-President, R. W. CHANEY, Berkeley, Calif.

Vice-President, P. S. WARREN, Edmonton, Alberta.

Secretary, H. E. VOKES, New York, N.Y.

Treasurer, ROBERT R. SHROCK, Cambridge, Mass.

Editor, C. WYTHE COOKE, Washington, D.C.

GEOLOGICAL SOCIETY OF AMERICA

For the year ending December, 1939

President, ELIOT BLACKWELDER, Stanford University, Calif.

Past-President, T. WAYLAND VAUGHAN, Washington, D.C.

Vice-President, Douglas Johnson, New York, N.Y.

Vice-President, E. L. BRUCE, Kingston, Ont.

Vice-President, RALPH W. CHANEY, Berkeley, Calif.

Vice-President, M. N. SHORT, Tucson, Ariz.

Secretary, C. P. BERKEY, New York, N.Y.

Treasurer, E. B. MATHEWS, Baltimore, Md.

Society Headquarters, 419 West 117th St., New York, N.Y.